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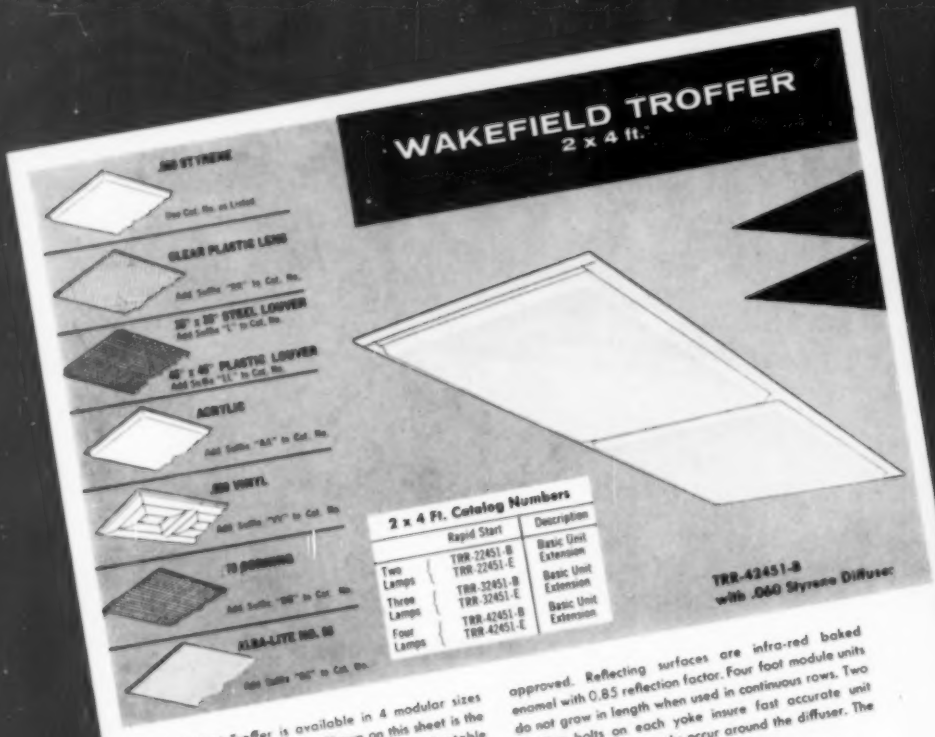
FEBRUARY 1959

ILLUMINATING ENGINEERING

Journal of the
ILLUMINATING ENGINEERING SOCIETY

Information You Can Use

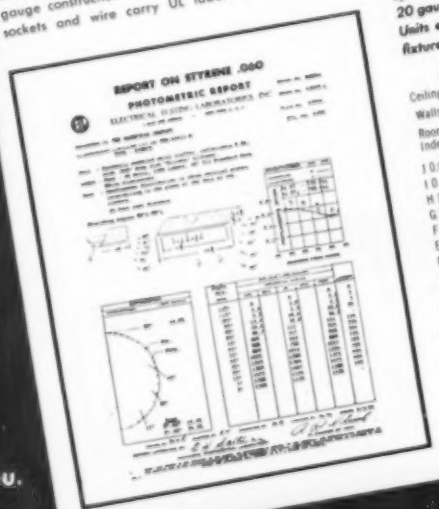


The Wakefield Troffer is available in 4 modular sizes with 8 types of light control. Shown on this sheet is the 2' x 4' size. The Wakefield Troffer line is adaptable to the ceiling constructions illustrated on the reverse of this page.

The over-all depth of the Wakefield Troffer is 4⅞". The body is one piece and is the standard Wakefield 20 gauge construction. All electrical components, ballasts, sockets and wire carry UL labels. Ballasts are CBM approved. Reflecting surfaces are infra-red baked enamel with 0.85 reflection factor. Four foot module units do not grow in length when used in continuous rows. Two leveling bolts on each yoke insure fast accurate unit installation. No light leaks occur around the diffuser. The 8 types of light control are shown above.

Limitations:
Check recessing depth and compatability of unit with ceiling type.

Specifying points for Architects and Engineers: One piece 20 gauge steel body. Infra-red baked 85% R. F. enamel. Units exactly four foot module. Four leveling bolts per fixture. No light leaks around diffuser.


REPORT ON STYRENE .060
PHOTOMETRIC REPORT

FLOOR REFLECTANCE = 10%

Ceiling	80%			70%			50%		
Walls	50%	30%	10%	50%	30%	10%	50%	30%	10%
Room Index	Coefficients of Utilization								
I 0.6	0.19	0.16	0.14	0.19	0.16	0.14	0.19	0.16	0.13
H 0.8	0.25	0.21	0.19	0.24	0.21	0.18	0.24	0.21	0.18
G 1.0	0.28	0.25	0.22	0.28	0.25	0.22	0.27	0.24	0.22
F 1.25	0.32	0.29	0.26	0.32	0.28	0.26	0.31	0.28	0.26
E 1.5	0.35	0.32	0.29	0.35	0.31	0.29	0.34	0.31	0.29
D 2.0	0.39	0.35	0.33	0.38	0.35	0.33	0.37	0.34	0.32
C 2.5	0.41	0.38	0.36	0.40	0.38	0.35	0.39	0.37	0.35
B 3.0	0.42	0.40	0.38	0.42	0.39	0.37	0.41	0.38	0.37
B 4.0	0.44	0.42	0.40	0.44	0.42	0.40	0.42	0.41	0.39
A 5.0	0.46	0.44	0.42	0.45	0.43	0.42	0.44	0.43	0.41

NOTE: The coefficients of utilization are based upon data given in Illuminating Engineering, P. 385 to 417, Vol. 51, No. 5, May 1956, Calculating Coefficients of Utilization.
IES curves and coefficients of utilization available on all diffusers.

April 21, 1958

This is one of several dozen "spec" sheets, printed on both sides, giving concise data on Wakefield's many commercial and industrial lighting units. We'll be glad to send them to you.

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When the authorization form is approved, it will be returned and new ballasts for replacement will be shipped directly to the job location without charge. After the new ballasts have been installed, the inoperative ballasts must be returned directly to Advance Transformer Co. for complete analysis and final approval.

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Louis Dunn
PRESIDENT

ADVANCE TRANSFORMER CO.

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ILLUMINATING ENGINEERING

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

February 1959

Vol. LIV, No. 2

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ILLUMINATING ENGINEERING SOCIETY

EDITORIAL and advertising offices
1860 Broadway, New York 23, N. Y.

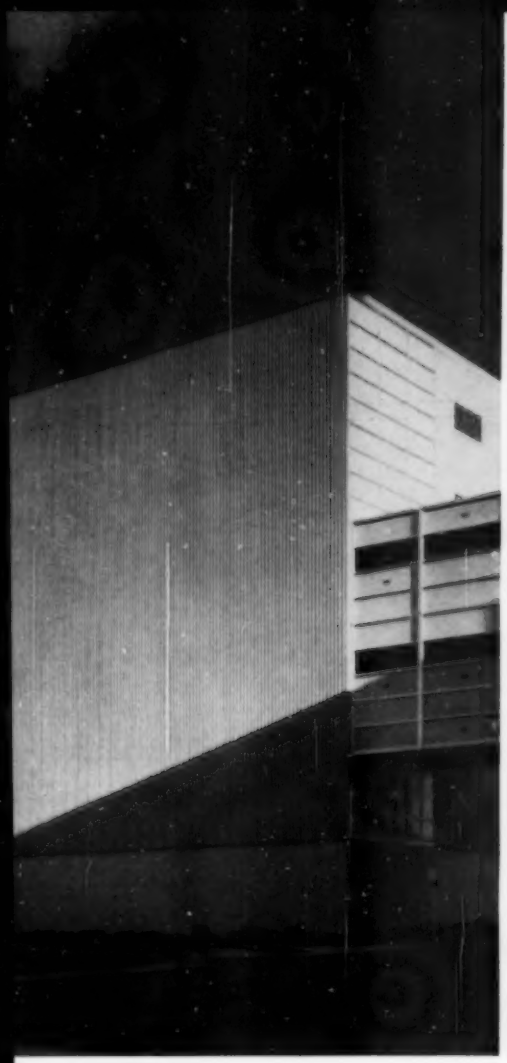
PUBLICATION office 32d Street & Elm Avenue, Baltimore 11, Md.

Founded 1906

ILLUMINATING ENGINEERING: The Journal of the Illuminating Engineering Society. Copyright 1959 by the Illuminating Engineering Society. Published monthly in the United States of America. Entered as second-class matter at the Post Office, Baltimore, Md. Acceptance for mailing at special postage rates provided for in Section 1103 P.L.&R., Act of October 3, 1917. Authorized July 16, 1918. ¶ Subscription $18 per year plus extra postage to all countries to which second-class postage rates do not apply; single copies $1.50. ¶ Address changes must be received at I.E.S. headquarters by the first of the month to be effective with the issue of the next succeeding month.

■ Hallmark Cards, Kansas City, Mo., where Curtis Visioneers "personalized" the illumination system in keeping with the products of the company. Architect & Consulting Engineer: Welton Becket.

■ Curtis Vari-Spots produce attractive lighting patterns in several lobbies of the Hallmark Cards building. Reception room shown is approximately 45 ft. by 45 ft. Vari-Spots are used here to accent two areas. Each is impressively dramatized.



■ General office. Curtis Alzak aluminum low-brightness troffers assure glare-free illumination throughout the area, combining visual well-being with visual charm.

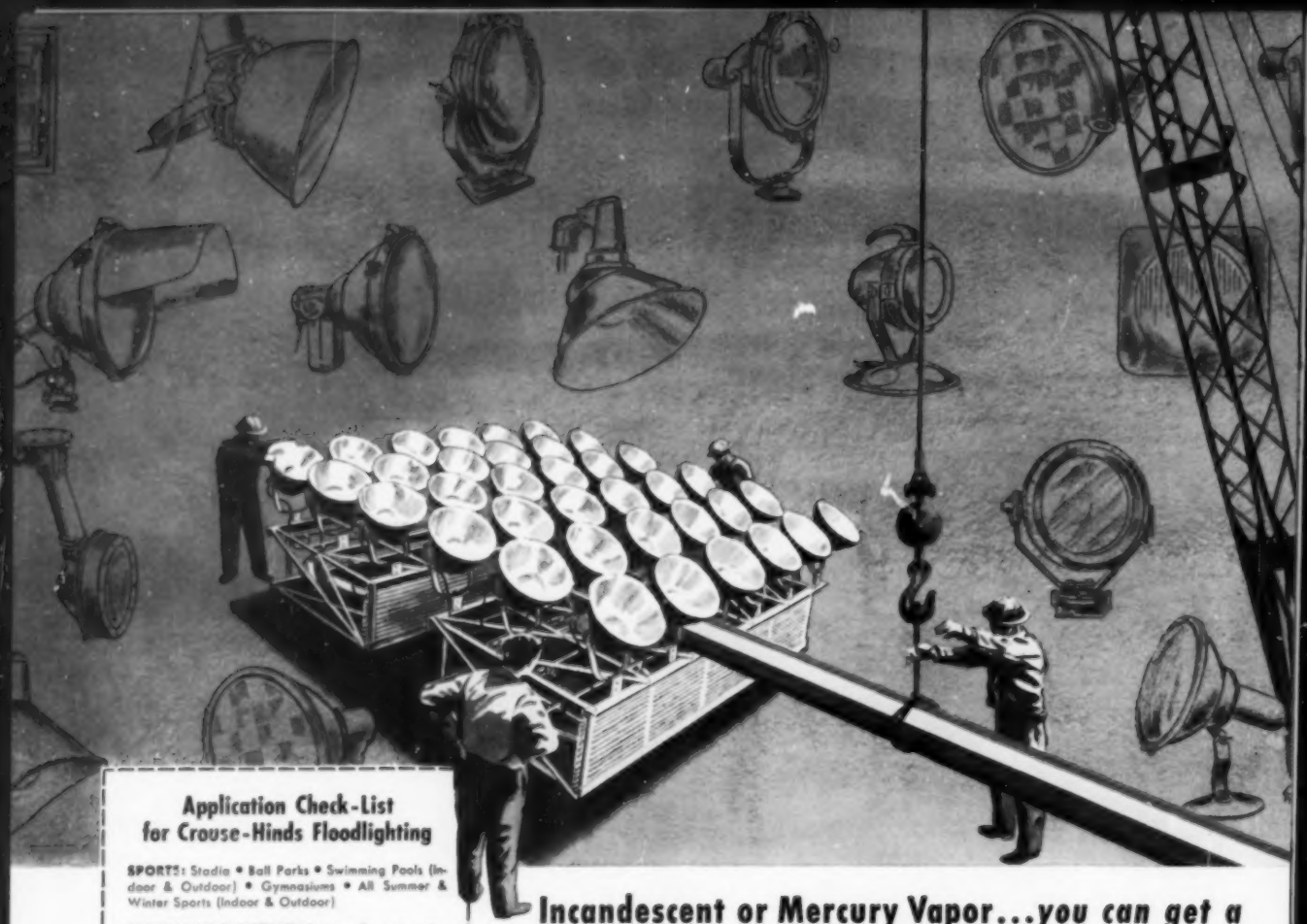
Curtis Lighting helps Hallmark Cards say "Welcome!"

Special illumination effects in greeting card building . . . accent high visual comfort . . . create a feeling of friendliness

It's only natural that a greeting card company would want to capture the spirit of its product in its headquarters building. And that was done at Hallmark Cards, Kansas City, Missouri. Technically, the lighting problem called for a system that would be uniform throughout the structure, yet provide the same glare-free illumination in rooms of various sizes. The assignment clearly prescribed Curtis Visioneering. The desired result was effected when Curtis designed a lighting system combining Curtis Alzak aluminum low-brightness troffers and Curtis Vari-Spot recessed incandescent units. The careful application of Curtis products completed the theme of visual charm and warm greeting, thus accentuating the aesthetic characteristics of the Hallmark Cards building. For assistance on your lighting problems write for the name of the Curtis Visioneer nearest you. Curtis Lighting, Inc., 6135 W. 65th Street, Chicago 38, Illinois. In Canada: 195 Wicksteed Avenue, Leaside, Toronto 17, Ontario.

CURTIS

Visioneers in Planned Lighting



Application Check-List for Crouse-Hinds Floodlighting

SPORTS: Stadia • Ball Parks • Swimming Pools (Indoor & Outdoor) • Gymnasiums • All Summer & Winter Sports (Indoor & Outdoor)

DECORATIVE & DISPLAY: Statues, Fountains, Memorials & Monuments • Public Gardens • Building Fronts & Entrances • Park, Playground & Cemetery Entrances & Interiors

BUSINESS: Shopping Areas • Drive-Ins, Outdoor Theaters • Building Fronts & Entrances • Recreation Parks • Gas Stations

AIRPORT: Ramps • Boarding & Loading • Street & Road Approaches to Airport • Markers & Beacons • Emergency Portables

CONSTRUCTION: Roads & Streets • Dams, Seaways & Piers • Detours • Buildings • Reconstruction of Disaster Areas

INDUSTRIAL AND UTILITY: Parking Areas • Freight Yards • Weigh Stations • Docks & Piers • Staging Areas • Production Work Areas

TRAFFIC: Tunnels • Viaducts • Bridges • Underpasses • Walks • Public Squares, Thruway Interchanges & Rest Areas • Cloverleafs • Parking Areas

UNDERWATER: Swimming Pools (Indoor & Outdoor) • Marine Life Displays • Municipal Garden Pools • Aquariums • Divers' Portable Units

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A quick scanning of the widely varied applications included in the Check-List at left proves again that floodlights often provide *better light from few source points at less cost* than conventional lighting.

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Re-lighting— On the Docket

Sometimes overlooked, or underestimated, the need for up-to-date lighting which meets recommended practice is as great in city and county governmental buildings as in any other area. Too often the processes of law and order are conducted under lighting systems installed 40 to 50 years ago when the buildings were first constructed.

Alleviating this condition and providing comfortable environments for all due process of law made the installations shown here entries in IES Section/Chapter My Most Interesting Lighting Job contests.

It isn't often that City Hall burns down, but it happened in Chicago, offering an opportunity for a brand-new lighting system. Before the fire was brought under control, the Council Chamber was completely destroyed. And in the re-building, which began almost immediately, the lighting was designed into the architectural scheme. Characteristics requested of the lighting system were:

(1) Good over-all illumination for a variety of intended uses;

(2) Varying footcandle levels in several areas without obvious brightness contrast—from 40 footcandles general to 70 at the rostrum;

(3) Minimum reflected glare from the specular surfaces, including the large highly-polished marble front wall, glass-walled visitors' gallery and the polished walnut desks.

(4) Balance of color to enhance the materials and fabrics selected by the architect;

(5) Protection from direct glare for the visitors' gallery on the second level of the room;

(6) Pleasant over-all environment.

To preserve the clean, uncluttered architectural design, completely concealed or recessed equipment was chosen. A combination of incandescent and fluorescent sources was selected for their color rendition.

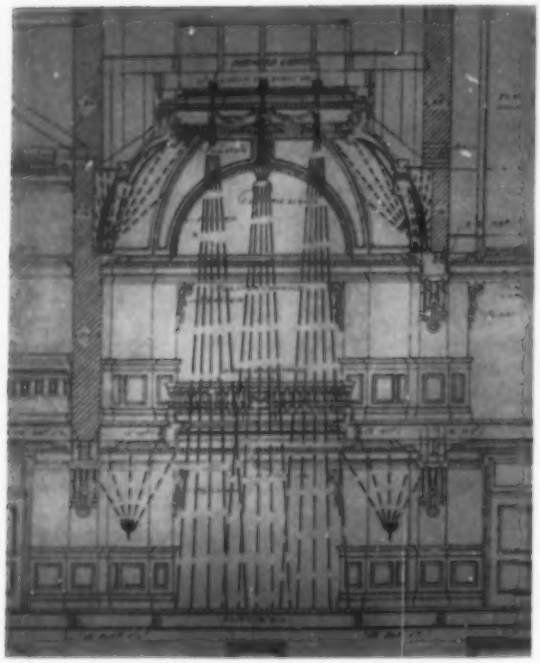
A suspended floating ceiling, part of the architect's plan, provided the means for recessing the incandescent downlights. Deep recessing was needed to prevent reflected glare from the marble wall and direct glare in the visitors' gallery. These units are equipped with parabolic Alzak aluminum reflectors. Around the perimeter, 300-watt flood

City of Chicago Council Chamber

This installation won second prize in the Chicago Section's contest. Lighting was designed by C. T. Wallace, Curtis Lighting Inc., Chicago, Ill.

lamps are used; 300-watt spot lamps elsewhere. The perimeter units lighting the rostrum have adjustable reflectors. Also highlighting the platform area is recessed lighting from vertical troffers installed behind the marble wall on either side.

The floating ceiling also provided a cove for wall lighting. Single-lamp fluorescent strip units are wired on dimming ballasts for operating the 40-watt T12 rapid-start standard warm white lamps. Average illumination levels are those aimed at — 70 footcandles at the rostrum and 40 in the general seating area.



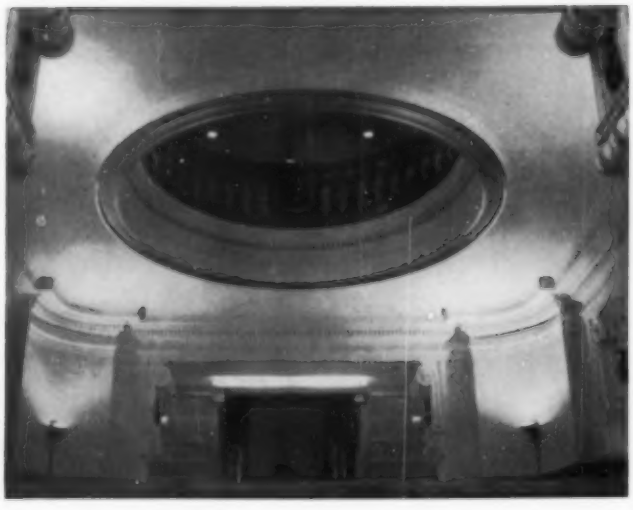
Cross-section of dome, taken from original 1897 prints, with new lighting superimposed on it.

Ingham County Court House

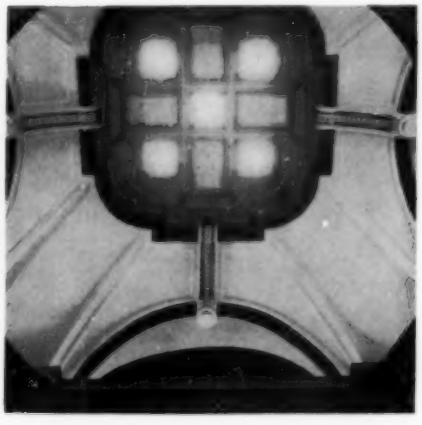
The dome area at Ingham County Court House, Mich., is not in the court room, as is more usual, but houses the stairs, circular balustrade and the main entrance. Distance from the top of the dome to the landing on the first floor is 36 feet.

Originally the top of the dome contained nine painted glass panels through which sunlight was supposed to have supplemented the artificial light. In practice, this proved of no value. These panels were replaced by painted ¾-inch plywood and five 300-watt recessed downlights. Four paintings in the dome, of early pioneer days in the county, are lighted by eight 20-watt fluorescent strips in each of the existing coves. Urns in the first floor entrance area provide indirect lighting which blends with the downlighting.

The court house lighting of which this is a part won second prize in the Western Michigan Section's contest. Lighting was designed by Dewayne R. Evans, Lighting Advisor, Consumers Power Co., Lansing, Mich.



First floor landing, left, and interior of dome, below, after re-lighting.



Clark County Court House

This installation won second prize in the Midwestern Regional contest, having taken top honors in the Indiana Section. Robert Kempf, Jeffersonville, Ind., was general contractor; Metzger Electric Co. of Clarksville, Ind., was electrical contractor. Lighting was designed by D. E. Harrington, Public Service Co. of Indiana.

Because the seeing tasks ranged from easy to critical, a re-lighting program was called for in the 1,920-square-foot court room in Jeffersonville, Clark County, Ind., to raise the levels from their former 15 footcandles. And the lighting system was not to detract from the Victorian dignity of the room.

Lawyers who use the court decided upon the floor and furniture arrangements. A geometric pattern of lighting units was then designed, to conform with the seeing tasks. Formed plastic-dish fixtures, in 4- by 4-foot and 2- by 4-foot sizes are recessed into a metal pan acoustical ceiling. Lamps are 48-inch T12 rapid-start standard cool white. Initial illumination level was 65 footcandles.

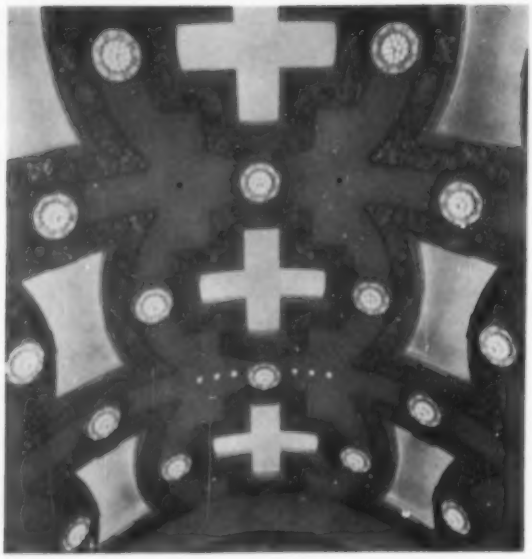
Surface reflectances are: ceiling 78%; plaster walls 60%; panel walls 27%; floors 16%. Brightnesses in footlamberts are: draperies 10 and 27; carpet 15; furniture 22; walls 30; tile floor 15.

City of Oakland Council Chamber

Until recently, the City of Oakland, Calif., Council Chamber, located on the third floor of the City Hall, was equipped with electrical fixtures and furnishings dating back to its construction some 45 years ago. Rather extensive electrical alterations were necessary in the plans for modernization, since the existing fixtures used for general illumination created considerable glare in the arched ceiling and produced only five footcandles at desk level.

Seal of the City of Oakland is the basis for the decorative motif, being woven into a seven-foot diameter section of the rug at the center. At the front on a raised dais is the Mayor's desk and around the circular Seal are the curved desks of the eight councilmen.

The central area is lighted by eight 1000-watt downlights mounted nearly at the center of the arched ceiling. The consulting decorator requested that the rosette fixtures be retained, to carry out the architectural design of the ceiling. These rosettes use long-life low-brightness lamps. Indirect



lighting is provided by industrial-type fluorescent luminaires mounted at the sides of "eross" and "curved side" coffers and aimed at the ceiling of the coffer. These reduce brightness contrast with the rosettes and increase the general lighting level.

Cornice lighting is completely new. Lamp holders were installed inside the column area and sufficient plaster removed to allow light from the reflector lamps to wash the ceiling in the council and gallery areas. Accent lighting for flags is with 1000- and 750-watt angular downlights mounted at the plaster domes over the center rectangular recesses. Maximum lighting level at the center Seal is 70 footeandles, with 40 footeandles on the council desk tops.

This installation won third prize in the Golden Gate's contest. Lighting was designed by Conrad S. Ottaway, Electrical Engineer with the City of Oakland, Calif.

In the re-lighting of the Reference Library at Chicago City Hall, separate and distinct areas are indicated by the use of several types of lighting systems. The ceiling varied in height over these areas, and was also eluttered with unsightly pipes and ducts.

The general reading room, where documents and newspapers are studied, requires high levels of illumination. For this area, about 90 footeandles are provided by a luminous ceiling of corrugated vinyl panels. This treatment also conceals the pipes and ducts. In the clerical portion of the library, 40-watt two-lamp recessed troffers, with 45- x 45-degree cut-off polystyrene louvers, provide a minimum of about 45 footeandles (along the walls).

A different effect is created in the librarian's office, where four 2- x 4-foot surface mounted units are installed end-to-end. These each have four 40-watt rapid-start lamps above the 2- x 2-foot acrylic panels. Brightnesses in the room vary from 13 footlamberts on the floor to 120 footlamberts on the luminous ceiling.

Chicago City Hall
Reference Library

Lighting was designed by G. Loren Benbow, Benjamin Electric Manufacturing Co., Des Plaines, Ill. This entry won third prize in the Chicago Section's contest.

Outdoor Applications of

New Reflector Contour Designs for Higher Output Fluorescent Lamps

By S. C. PEEK
J. P. KEENAN

Introduction

The general lack of surrounding surfaces from which interflections can occur in outdoor lighting puts special emphasis on control in luminaire design. Furthermore, lighting engineers, and the public as well, are becoming more and more aware of the glare which is quite serious in many outdoor installations. This paper describes a few practical applications of a concept which is of value in the design of linear light source reflectors which maximize control and minimize glare. The concept is described in a companion paper entitled "Controlled Fluorescent Reflector Design for Sharp Cutoff and Uniform Distribution" by Domina Eberle Spencer. It will suffice here to outline only its basic principles.

(1) A family of specular reflector contours are designed to be filled with an image of the light source as viewed from the most remote point to be illuminated.

(2) A method of calculating the illumination (its three vector components) at any point is given. This method of computation makes no assumption concerning relative reflector size and distance to the point to be illuminated. In other words, it does not depend on the inverse square law.

(3) A method of shielding the light source, with no sacrifice of illumination at the most remote point to be illuminated, is presented. All this results in some very practical advantages as will be demonstrated by the applications described herein. The advantages over previous methods of reflector design are:

(a) a single lamp per luminaire can produce as much illumination at a remote point as is possible with several lamps used with other reflector designs,

(b) a high degree of uniformity of illumination can be obtained, and

(c) the almost complete shielding makes low mounting feasible and results in little glare for high mounted applications.

Before proceeding with the applications, it would be well to point out that the recent introduction of higher brightness fluorescent lamps has given impetus to, and in some cases, made possible the installations to be described. Since the concept states that the illumination from a specular reflector is dependent upon its brightness and area as viewed from the point to be illuminated, the brightness of the light source and not its total lumen output is the most important factor. It is also important that the lamp be of uniform brightness so that its image and resultant illumination will also be uniform. One other breakthrough which has helped to make this practical is the development of aluminized Mylar films. These films can be applied to most any surface material and when bonded to aluminum an 84 to 87 per cent reflectance is obtained. The reflector surface is protected by a Mylar film which is impervious to weathering. Heretofore, specular surfaces were hard to obtain and often inefficient after several years of exposure to the elements.

Low Mounted Applications

The low mounted applications will be described only briefly, since one was described for airport

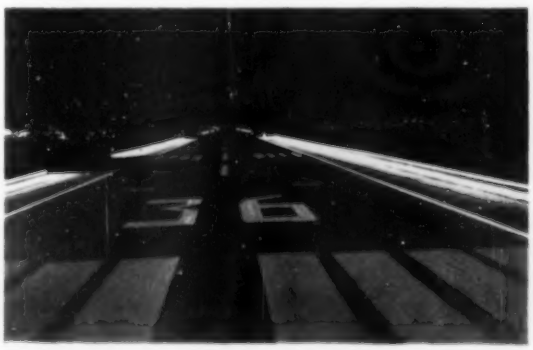


Figure 1. Photograph of actual landing at Washington National Airport with low mounted fixtures.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, August 17-22, 1958, Toronto, Ont.
AUTHORS: Sylvania Electric Products Inc., Salem, Mass.

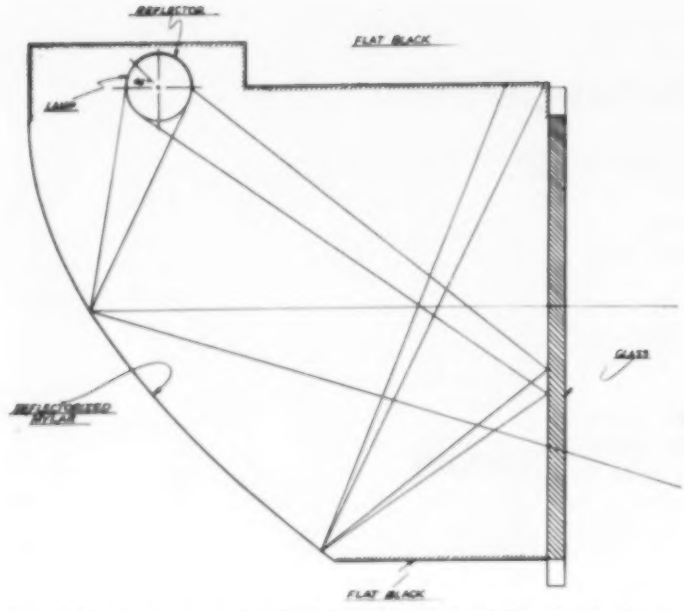


Figure 2A. Schematic drawing of the lamp and luminaire showing how various rays are reflected.

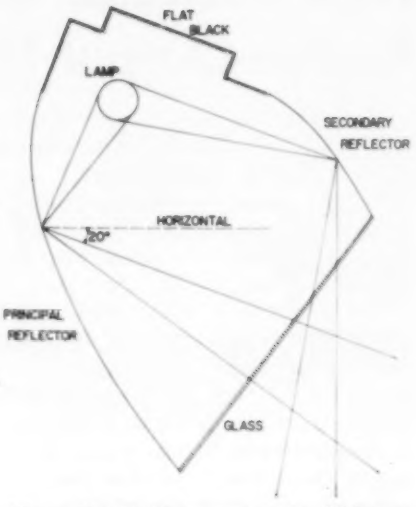


Figure 2B. Reflector contour for 20-degree luminaire.

use in a previous paper. Fig. 1 shows an installation at the Washington National Airport. Thirteen hundred feet of the touchdown area are illuminated by two continuous strips of reflectors using eight-foot VHO fluorescent lamps. The lamps were operated from a series circuit which employed a ballast specially designed for this application. The reflectors have a contour as shown in Fig. 2A and resulted in very little glare as viewed from the cockpit. The same luminaire has been installed on 500 feet of the New Jersey Turnpike. Fig. 3 shows a night-time view of this installation, together with an overhead system, both of which are being evaluated with respect to their performance in fog.

High Mounted Applications

Fig. 2B illustrates the reflector contour for the so-called 20-degree luminaire. The "20-degree" refers to the cut-off, and is illustrative of the distance that can be illuminated for a particular mounting height. The candlepower distribution and resultant isolux plot is contained in Dr. Spencer's paper.

Fig. 4 is a night view of a parking lot installation employing eight luminaires of this design. Each employs one eight-foot VHO lamp and is mounted at 25 feet. The fixture brightness is below 350 footlamberts when viewed from above the cut-off angle. In fact, the glare is almost too low, for some ultimate users would like to have the source of illumination more obvious for commercial reasons. The author, however, has the strong conviction that low brightness outdoor luminaires have a future; as the public becomes more accustomed to good lighting, it will demand it. Perhaps, we of the lighting industry would like to show off our goods by shining them in people's eyes; however, we will be performing a better service by lighting surfaces which tell their own sales story in a way which is clearer to the consumer and is certainly less aggravating.

This design produces over one footcandle on a

Figure 3. Nighttime view of low mounted installation at New Jersey Turnpike together with an overhead system.

Figure 4. Nighttime photograph of parking lot installation using controlled fluorescent.

horizontal surface at 50 feet from the base of a luminaire mounted 25 feet high; all this from a single VHO lamp in a reflector only 9 inches wide. It is interesting to note that an 18-inch wide reflector would produce twice this amount again, with only one lamp. The candlepower distribution curve shows practically no light above 70 degrees. This is very uncommon for fluorescent luminaire designs, and makes possible the low mounting heights. This, of course, is of economic advantage and also results in more light on vertical surfaces.

Vertical Surface Floodlighting

There has been recent emphasis on floodlighting of vertical surfaces by means of fluorescent lamps. Vertical surfaces are easily seen at a distance and can be used to convey a sales message. Store or gas station fronts, gas station pumps and billboards are all examples of this. Concentrated source floodlights, such as incandescent lamps, tend to produce reflected glare and are expensive in power consumption. Ordinary fluorescent lamps and reflector designs are being used successfully in posterboard lighting where the total vertical height is of the order of 12 feet, but has resulted in serious nonuniformity when attempts have been made to project the light further.

With the use of the new technique, it was possible to synthesize a reflector contour which gave remarkable uniformity over much larger areas. In this case, uniformity was more important than cut-off, so no particular effort was made to obtain cut-off. The resultant vertical footcandle readings on a

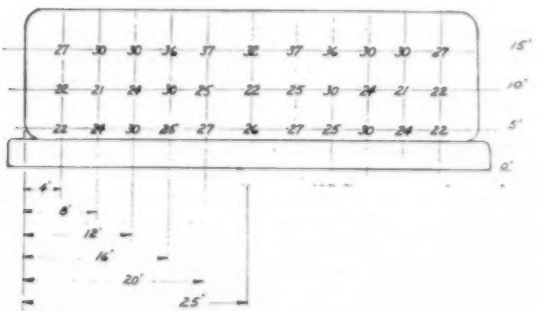


Figure 5. Vertical footcandle readings on a paintboard 20 feet by 50 feet; maximum footcandles — 37, minimum footcandles — 21, average footcandles — 27.3. Readings are vertical and corrected for angle.

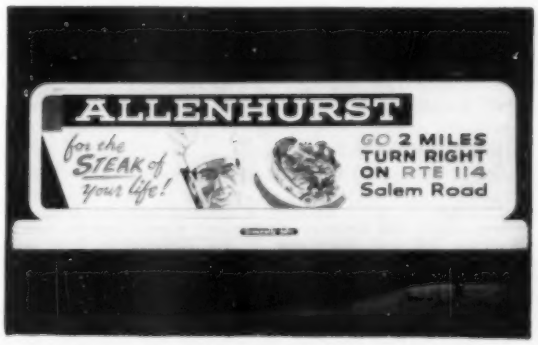


Figure 6. Paintboard illuminated by five luminaires using new reflector design Each luminaire contains one eight-foot VHO lamp.

paintboard 20 feet by 50 feet are illustrated in Fig. 5. Fig. 6 shows a photograph of this paintboard illuminated by five luminaires designed in the manner described. Each luminaire employs one eight-foot VHO lamp. Each reflector is 2 feet wide, and is mounted at the bottom of the bulletin. The luminaires are made of aluminum with aluminized mylar reflecting surfaces and are equipped with Plexiglas windows.

Conclusion

The advent of higher brightness fluorescent lamps of uniform cross-section, the availability of aluminized Mylar reflecting surfaces and the development of a mathematical concept to handle reflector design have all combined to make possible fluorescent luminaires of improved characteristics.

Many outdoor uses for fluorescent lamps have been conceived, but discarded because of the apparent lack of control possible with this light source. It is hoped that these can now be re-evaluated in the light of the concepts described herein.

DISCUSSION

A. L. Hart:* Most lighting engineers have been aware that to obtain adequate control of a fluorescent lamp, large size specular reflectors are needed. Work published by W. F. Potter in 1940 established this need. Railing floodlighting installations in 1949 on the roadways over the Grand Coulee and Shasta Dams indicated that low level mounting of fluorescent lamps in specular reflectors could produce highly acceptable results. In 1954, a combination parking area - building floodlighting unit was installed around a parking quadrangle in Nela Park, Cleveland. The unit was designed to provide shielding such that an approaching driver never saw the lamp or its image in the reflector.

In the design of outdoor luminaires, low brightness at normal viewing angles is, of course, commendable as is uniform illumination, and there are undoubtedly many critical outdoor seeing tasks where complete lack of luminaire brightness and extreme uniform illumination such as shown in Fig. 11 of Dr. Spencer's paper.[1] However, there is some question as to whether these factors are essential enough in a non-critical application such as parking lot lighting to justify deliberate absorption of almost 50 per cent of the lamp lumens by a black reflector. The brightness of most pavement surfaces will be non-uniform anyway at normal viewing angles; hence, a reduction in utilization on the basis of uniformity would not appear practical.

1. Spencer, D. E.: "Controlled Fluorescent Reflector Design for Sharp Cut-Off and Uniform Distribution," a paper presented at the National Technical Conference of the Illuminating Engineering Society, August 17-22, 1958, Toronto, Ont., to be published in Illuminating Engineering.

W. B. Elmer:** This paper is a valuable contribution to the literature in that it represents a better engineered approach to the use of fluorescent lamps for outdoor lighting. In roadway lighting in particular, any sincere engineer must grit his teeth in frustration at the poor efficiency, inability to meet IES Recommended Practice distribution and the substantial glare actually obtained from most present-day fluorescent luminaires. The work done by Spencer and the authors in producing their new designs provide, for the first time, a suitable vertical distribution with good cut-off from a fluorescent luminaire; one that can equal that obtainable from mercury and incandescent luminaires. The lack of lateral control still cannot be overcome, so these new designs cannot provide high utilization for roadway lighting unless mounted longitudinal to the roadway. Some acceptable compromise with efficiency may be obtained with diagonal mountings on highway medial strips and it is hoped that further work will be done in this direction.

The authors are to be commended for their philosophy in being aware of the concept of economy in the use of light. Witness their statement: "A single lamp per luminaire can produce as much illumination at a remote point as is possible with several lamps used with other reflector designs." This attitude is most refreshing. It is certainly contrary to the urge common to many illuminating engineers to "sell up." Many in our profession need to consider, in general, whether or not we are promoting the use of more electricity and more light or *better* and *more economical* lighting. The authors' approach, based on this latter viewpoint, is most welcome.

S. C. Peek and J. P. Keenan:* We wish to thank Mr. Hart and Mr. Elmer for their comments.

Mr. Hart suggests that quantity of light is more important than quality in many outdoor applications. This conclusion, however, is not in agreement with visual facts. If one is interested in ability to see fine details, quantity and quality cannot be considered independently. The usual outdoor lighting produces useless mounds of light close to the luminaire and little elsewhere. Both the non-uniformity in distribution on the illuminated surface and the glare from the luminaires prevent one from becoming adapted to the task. If direct glare can be eliminated and if the uniformity of lighting of the task is improved, visual benefits will be very great. Improvement in quality will be more beneficial visually than large increments in the quantity of light.

There is only one way in which high quality outdoor lighting may become a disadvantage. This is the case in which glare acts as a means of attracting the public and thus serves a useful (though non-visual) purpose.

We are entirely in agreement with the suggestion that one of the criteria used in this paper is not entirely satisfactory. We have followed current practice in street lighting in designing for uniform distribution of the incident light. This ensures a uniform appearance of the pavement only if it is a perfectly diffusing surface. It is well known that pavement surfaces are far from perfectly diffusing. However, despite a large amount of experimental work, an adequate method of specifying pavement surfaces is not yet available. Current measurements are dependent on the exact details of the experimental set-up and do not permit the prediction of the appearance of pavements under new systems of lighting. When the problem of specifying pavement reflectance in a significant fashion is solved, we can look forward to new criteria for street and runway lighting which will be of actual visual significance.

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**Wheeler Reflector Co., Boston, Mass.

*Authors.

INSTALLATION IN THE RESIDENCE OF WILLIAM P. FINNERAN, COLUMBUS, OHIO.

Functional Decorative Lighting For a Hall and Stairway

LIGHTING OBJECTIVE: To provide general illumination and decorative lighting for an interior hallway and staircase.

GENERAL INFORMATION: This bedroom hallway is 22 feet long, 4 feet 2 inches wide and has an 8-foot high ceiling. The walls are papered (turquoise background with black and white "invisible" plaid, 40 per cent average reflectance). The carpet for hall and stairway leading down to a recreation room is sandalwood, 35 per cent reflectance. Stair well ceiling is white, 80 per cent reflectance.

INSTALLATION: Recessed in the hallway ceiling is a 100-watt Prescolite No. 811-6611 box with dropped opal glass cover. A lighted soffit (see Figs. 2 and 3) over the louvered and brick wall on the hallway side of the divider uses frosted glass as shielding. The average illumination in the hall 30 inches above the floor is 20 footcandles with all lighting equipment in use.

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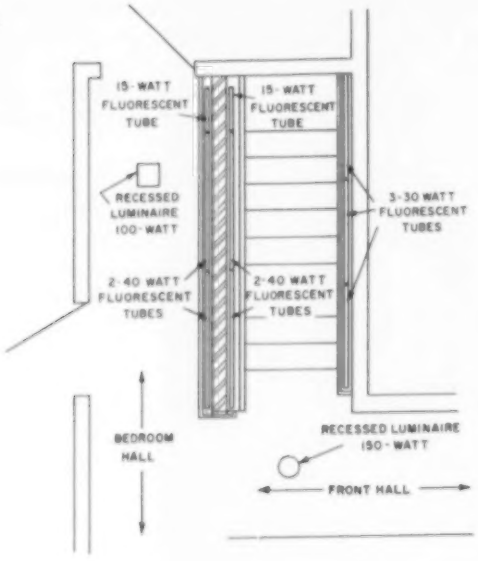

Figure 2. Plan view of hall and stairway.

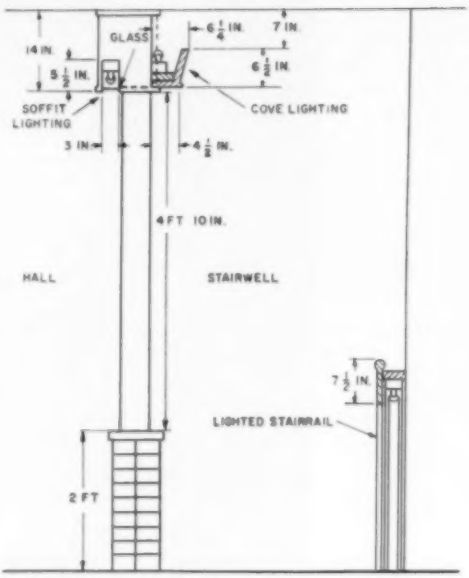

Figure 3. Section showing soffit, cove and stair rail lighting.

General illumination for the stair well is furnished by a Lightolier No. 7946 150-watt unit at the head of the stairs and by a cove over the louvered divider. The stair railing at the right has a 7½-inch apron concealing three 30-watt fluorescent tubes which light the treads. With all lighting equipment in use, the average illumination down the center of the stair well at 30 inches from the treads (and therefore not including the illumination from the stair rail lighting) is 10 footcandles; the average on the stair treads is 25 footcandles.

Lighting designed by Helen W. Marriott, Home Lighting Advisor, Columbus and Southern Ohio Electric Co., Columbus, Ohio; builder: William P. Finneran, Columbus, Ohio.

Lighting data submitted by Helen W. Marriott as an illustration of good lighting practice and to aid in the design of similar installations.

Published by the Committee on Publications of the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

Evaluation of Performance of

Polystyrene Components of Fluorescent Luminaires In Actual Service and Under Accelerated Testing

By D. A. POPIELSKI
R. A. McCARTHY

DISCOLORATION of polystyrene (styrene) fixture components used for illumination control of fluorescent lighting does not follow a single time-color change pattern. Although many installations have given five years or longer service life without objectionable yellowing, instances of shorter acceptable service life have been significant in number. Impurities in styrene were a significant factor in many cases, but improvements in styrene production techniques have reduced this cause of rapid discoloration to a minimum. Other factors, not connected with styrene purity, have been found to be important.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, August 17-22, 1958, Toronto, Ont. AUTHORS: Monsanto Chemical Co., Plastics Division, Springfield, Mass. This paper accepted by the Papers Committee of I.E.S. as a Transaction of the Illuminating Engineering Society.

Lamp Type and Plastic-to-Lamp Distance

The discoloration of styrene subjected to ultraviolet light exposure is dependent on the intensity and the wavelength of the light emitted. The wavelengths in the near ultraviolet below 400 mμ) are particularly destructive to styrene. Since the intensity varies with the distance of the lamp to the plastic diffuser or light shield, the shorter this distance, the greater the destructive effect. Therefore, lamp selection and positioning affect the discoloration rate. Figs. 1 through 6 illustrate the increase in yellowness in general purpose styrene, with time, when exposed to six different 40-watt T-12 fluorescent lamps. The effect of five different positioning distances is also shown.

The samples for this testing were mounted so as

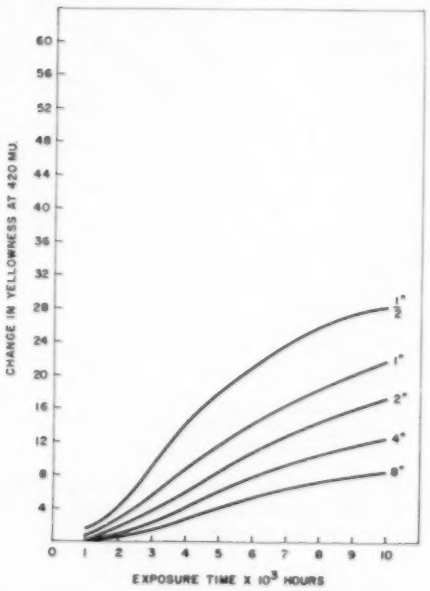

Figure 1. Effect of exposure time to 40-watt T12 daylight fluorescent lamp on white pigmented styrene at varying plastic-to-lamp distances.

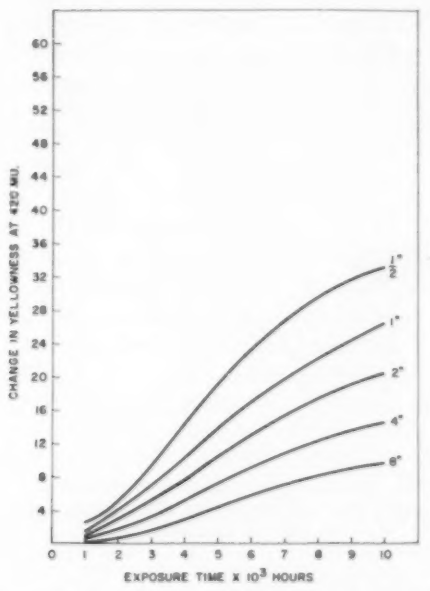

Figure 2. Effect of exposure time to 40-watt T12 standard warm white fluorescent lamp on white pigmented styrene at varying lamp-to-plastic distances.

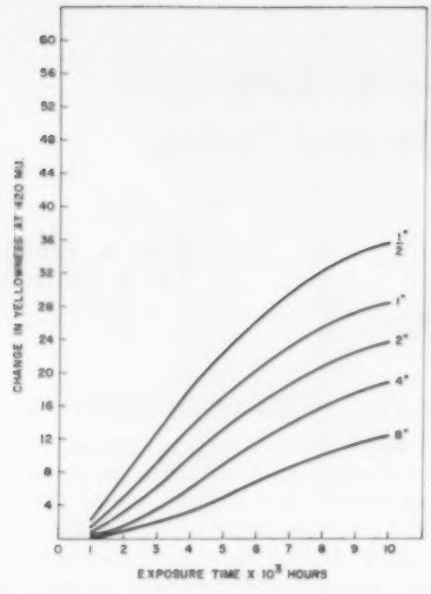

Figure 3. Effect of exposure time to 40-watt T12 standard cool white fluorescent lamp on white pigmented styrene at varying lamp-to-plastic distances.

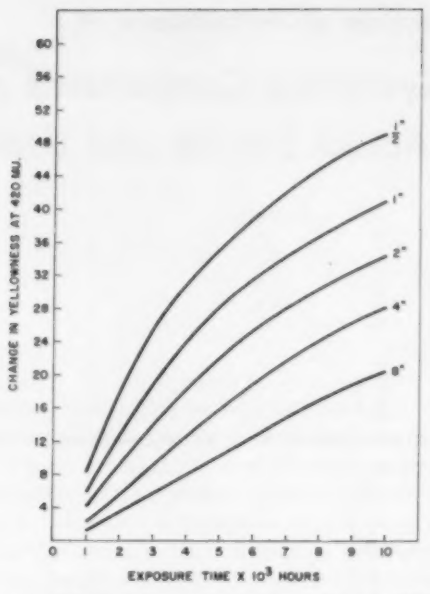

Figure 4. Effect of exposure time to 40-watt T12 soft white fluorescent lamp on pigmented styrene at varying lamp-to-plastic distances.

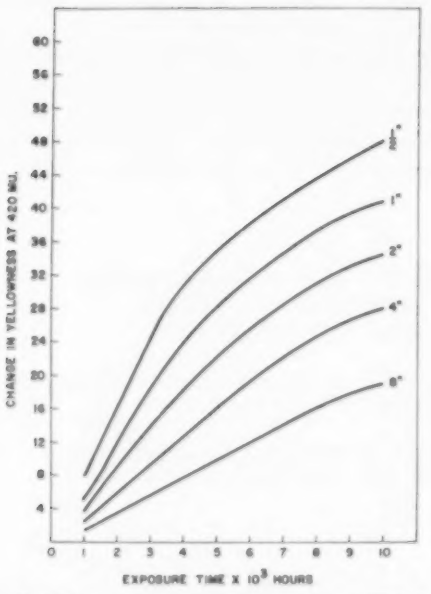

Figure 5. Effect of exposure time to 40-watt T12 deluxe cool white fluorescent lamp on white pigmented styrene at varying lamp-to-plastic distances.

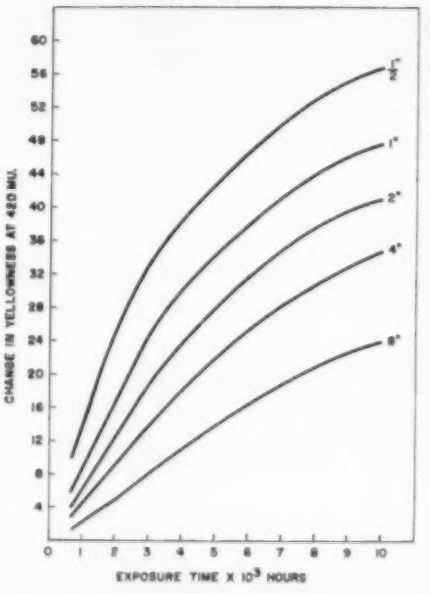

Figure 6. Effect of exposure time to 40-watt T12 deluxe warm white fluorescent lamp on white pigmented styrene at varying lamp-to-plastic distances.

not to obstruct free air passage keeping the black body temperature at 120-130F, which is believed to be a representative temperature in actual use. Higher temperatures increase discoloration rates. New lamps were used from one supplier but results from lamps of the same type from other suppliers are believed to give similar results since ultraviolet light emission is similar.[1]

Fig. 7 summarizes the data from Figs. 1 through 6, details the exposure time required for various lamp types and plastic to lamp distances to achieve similar discoloration increases. (The data concern unstabilized general purpose styrene but performance of ultraviolet stabilized general purpose styrene can be estimated by using a factor of 2.5, *i.e.* 2.5 longer exposure to obtain the same discoloration level.)

Yellowness increases for Figs. 1 through 6 were measured by the difference in reflectance at 420 mμ before and after exposure, instead of using transmission data and equations for calculating yellowing factor.[2] Fig. 8 shows the validity of the use of this procedure. The upper curves show the effect of fluorescent light radiation on the spectral curves of white pigmented styrene. The lower curve illustrates the difference in reflectance between the unexposed and most discolored samples. The greatest change takes place at 420 mμ. Therefore this point was selected as reflecting the greatest numerical change in yellowness and so the most sensitive measurement point.

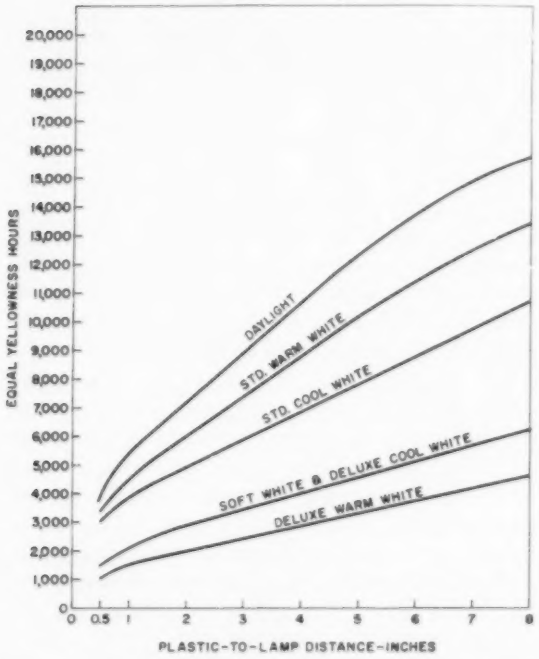

Figure 7. Equal yellowness hours of continuous exposure at various plastic-to-lamp distances for six common fluorescent 40-watt T12 lamps.

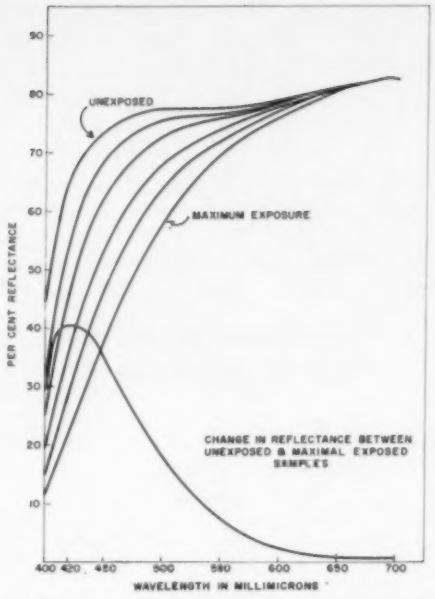

Figure 8. Effect of fluorescent light radiation on spectral reflectance curves of white pigmented styrene.

Fixture Design

Discoloration rates have been found to increase more rapidly for plastic body temperature rises above 120-130F. (Insufficient data are available to completely detail the relationship of temperature and discoloration.) Luminaire design which limits free air passage may cause plastic body temperatures to rise above 130F and so accelerate discoloration rates.

Fixture Maintenance Practices

Instances of discoloration of cleaning agents retained on the fixture and cleaning agent action to accelerate styrene discoloration are known.

If lamp type, distance from lamp to plastic, luminaire design or maintenance practices inadvertently combine unfavorably, unacceptable discoloration results from short term exposure for this otherwise satisfactory plastic. This fact led to the search for ultraviolet light stabilizers for styrene. Many chemicals were known which would improve the performance of styrene by absorbing ultraviolet light more rapidly than styrene. The choice of the most suitable involved investigation of such factors as compatibility, heat stability at fabrication temperatures, color quality, and the effect on styrene

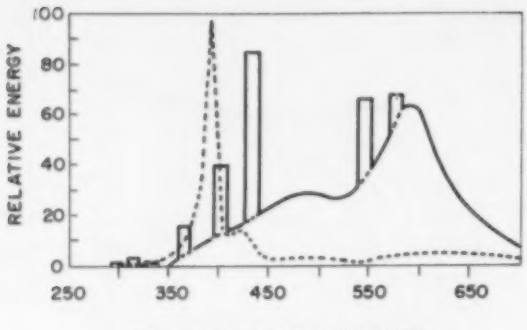

Figure 9a. Atlas Fadeometer.

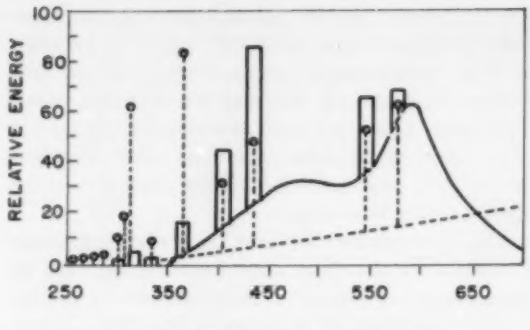

Figure 9b. S-1 Sunlamp.

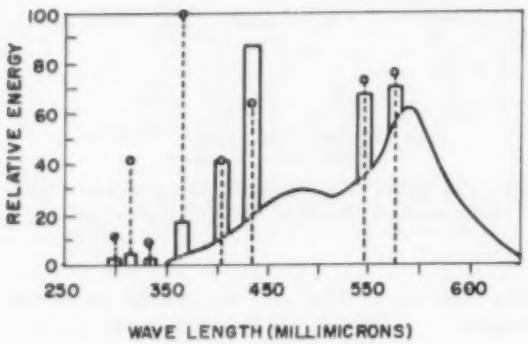

Figure 9c. Solar energy.

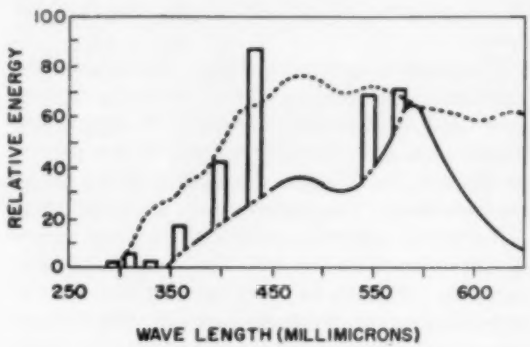

Figure 9d. UViarc.

mechanical properties. However, the selection of the optimum ultraviolet light absorber involved the study of accelerated aging tests, since actual "use" testing would involve many years of testing before judgment of an acceptable product could be made.

A method of accelerating ultraviolet light aging, to be of value, has to meet the following requirements:

(a) The wavelength of the light source must closely duplicate fluorescent light emissions so that extrapolation of short term testing results to estimate maximum use life would be possible.

(b) The test must be sufficiently accurate and reproducible to discriminate between levels of light stability achieved as formulae are varied either by quantity or type.

Tests Available

A study of the available tests reveals the following information in regard to their meeting the above requirements:

Fadeometer (ASTM 822-46T)—The Atlas FDAR Fadeometer has a carbon-arc light source with a Pyrex globe which limits the wavelength of light emitted. Samples are positioned in a cabinet at a fixed distance from the light source and rotated in a vertical plane around the light. Carbon rods must be renewed and the glass filter cleaned, daily. Normal test duration is 500 hours. This equipment was selected for IES-SPI-NEMA jointly proposed specification for Class C (ultraviolet light stabilized) styrene.[3] However, as shown in Fig. 9a, the spectral curve of the Fadeometer light source radiations has a maximum intensity of 390 mμ which is considerably different from the spectral curve of light emitted from a 40-watt T-12 standard cool white fluorescent lamp (an average lamp).

S-1 Sunlamp (ASTM 795-49T) — The light source has a tungsten filament and a mercury arc without a filter. Samples are rotated in a horizontal plane under the light source. Samples are cooled by circulating air and kept below 120 F. Normal test duration is 500 hours. The spectral curve obtained from the S-1 Sunlamp has considerable radiations below 300 mμ so that it is not completely representative of the radiations emitted by an average fluorescent lamp (see Fig. 9b). S-1 Sunlamps vary in intensity when new and decrease in intensity with use. The normal test duration and the service life of the bulb is 500 hours. Therefore,

it is difficult to obtain consistent light source intensity during any single test.

Solar Radiation (ASTM 1435-56T) — Samples are exposed to combined sunlight and skylight on a rack facing true south at an angle of 45 degrees to the horizontal. Significant data required six months to one year, depending on geographical location. The average radiation pattern compares closely to that of an average lamp (see Fig. 9c). Reproducibility problems are obvious, since the intensity of ultraviolet light energy of sunlight and skylight varies regionally, seasonally, and annually.

UViarc — The equipment is similar to that used with ASTM 795-49T. (#74A-10-700-watt mercury vapor lamp with #9700 Corex D glass filter.) The light source is a mercury discharge lamp with a glass filter which controls the wavelength of the light emitted. Samples are rotated in a horizontal plane under the light source. A 6-inch lamp to plastic distance is maintained. Sample temperatures are kept below 120 F, by circulating air. The glass filter cuts off radiations below 300 mμ and allows a spectral distribution resembling that of the average lamp but is conisderably stronger at 365 mμ (see Fig. 9d). The high intensity light source gives a high aging acceleration factor making test periods short. Significant judgment can be made after 150 hours of exposure or less. Since the service life of the light source is long (1000 hours), reproducibility problems due to changing intensity during a test are not significant.

Actual Exposure to Fluorescent Lamps — Three fluorescent lamps (standard cool white) in standard reflecting luminaires were used as a light source. Continuous exposure at 1½-inch plastic to lamp distance was used. Significant information for judgment was obtained after 1500 hours. Discoloration rates are relatively slow by this method, and long term aging data require at least 10,000 hours (14 months) of continuous exposure.

To confirm the judgment and comments of the previous section, tests were run using all five methods. Since duplicate tests were run on several pieces of the same apparatus, variations in light source intensity was noticed between instruments of the same type. To compensate for the variability in intensity, unstabilized samples of styrene were used as a control. Tests were carried out to a predetermined yellowness level in the control samples, rather than for fixed periods of time. As a result, as can be seen in Fig. 10, single curves were obtained from data accumulated from tests run at different times with different pieces of the same type of equipment.

While Fig. 9 indicates the degree to which the spectral discharge of test light sources duplicates that of an average fluorescent lamp, Fig. 10 illustrates the following:

(a) The relationship between accelerated tests by Fadeometer, S-1 Sunlamp, solar energy, UViarc, and actual fluorescent light exposure with a common factor of total light exposure.

(b) The degree to which artificially accelerated tests compare with actual fluorescent light exposure.

(c) The performance of a stabilized styrene to unstabilized styrene.

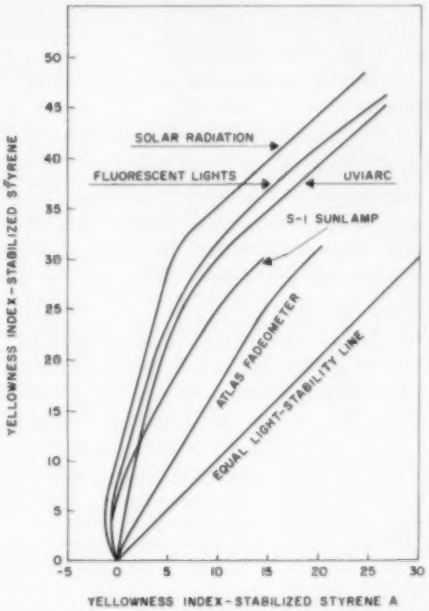

Figure 10. Lighting stability correlation between permatone styrene and unstabilized styrene under several accelerated tests.

Compensating for light intensity variation to correlate test results on stabilized styrene when two or more pieces of the same test equipment or different test methods are involved required a "common denominator" be developed. This "common denominator" would minimize the effect of light intensity variation existant in different units of the same design or test units of another design by essentially equalizing the total light incident on a sample irrespective of the light source.

The data in Fig. 10 represent the application of the "common denominator" as developed in our laboratories. This technique utilizes a control sample of unstabilized styrene of a known stability value. Tests are carried out by measuring incremental increases in yellowness of the stabilized sample when predetermined levels of yellowness are reached in the control sample of unstabilized styrene. The changes in yellowness (measured by reflectance at 420 mμ) are shown with the unstabilized styrene values plotted on the ordinate and the stabilized styrene values on the abscissa.

The "equal light stability line" is drawn to represent the hypothetical case when unstabilized styrene and stabilized styrene discolor equally, *i.e.*, no stabilization is achieved by the additives. Thus, the degree of improvement achieved by a stabilizing system can be measured by the extent to which the curve varies from the "equal light stability line."

Fig. 10 is of interest in that it illustrates the correlation of the various tests with actual exposure to fluorescent lights, the true criteria for testing a material to be used in fluorescent light fixtures. In addition, the value of the stabilizing effect of the "A" system is depicted together with the accuracy (assuming that actual exposure gives the true value with which each test represents the system's value. The curves obtained related to the "A" stabilizing system, since other systems may or may not show the same relationship.

The common factor* of the total amount of light incident on both a stabilized styrene and unstabilized styrene eliminated the time factor in Fig. 10. However, the curves for the Fadeometer and S-1 Sunlamp represent 500-hour tests; UViarc, 144 hours; actual exposure, 7500 hours; and exposure to solar energy, 300 days. The "equal light stability line" was added to Fig. 10 to depict a stabilizing of no value, *i.e.* equal to unstabilized styrene. If a more stable styrene is tested and compared to unstabilized styrene, a curve will result which will fall off the "equal light stability line" (if plotted as in Fig. 10). The greater the distance from the "equal light stability line," the greater the effectiveness of this stabilizing system.

The following conclusions can be drawn from Fig. 10:

1) At 10 units of yellowing of the stabilized styrene, the Fadeometer tests indicates a discoloration resistance approximately 1¾ times that of unstabilized styrene, the S-1 Sunlamp indicates 2½ times the color stability and the exposure to solar energy indicates 3½ times. Exposure to fluorescent lamps and the UViarc indicate that this stabilization system is approximately 3 to 3¾ times as resistant to discoloration by ultraviolet light as unstabilized styrene.

(2) The UViarc test which utilizes a light source closely duplicating the fluorescent lamp causes discoloration behavior in styrene most similar to that caused by fluorescent lamp exposure. Exposure to solar energy is next closest.

To determine if these results were specific to the stabilizations system used, a second series of tests was conducted. Here a stabilized styrene B was used as a control instead of unstabilized styrene, and a stabilized styrene C was tested. A newly developed glass filter was used on the UViarc to make it even more closely duplicate the spectral radiation of the average fluorescent lamp. This is marked Filter #2. Fig. 11 shows the results.

As can be seen, only the UViarc, with Filter #2 and exposure to solar energy, closely duplicate the results of exposure to the standard warm white fluorescent lamp. Other results are sufficiently different to be of no value in judging these stabilizing systems. The value of the UViarc test with the new filter is, therefore, obvious. Not only does this test accelerate, by approximately fifty times, the discoloration rate but is also specific for testing materials to be used in conjunction with fluorescent lights.

It is, therefore, believed that the factors involved in the previous performance of styrene as fluorescent light luminaire components have been isolated and that optimum performance can be obtained by proper selection of lamp type, plastic to lamp distance, luminaire design, and maintenance procedures. Since the installation and customer requirements preclude wide latitudes of choice in this regard, an improved stability styrene is required to compensate for adverse installation requirements. Since a test specific for this application is available to judge stabilizing systems, some ultraviolet stabilized styrenes have been developed and are in current use. We are confident that improved ultraviolet light stabilized styrenes will be developed, utilizing the UViarc test, which will show further improvement in discoloration resistance to the ultraviolet light from fluorescent lamps. In addition, short range programs are being carried out in our laboratories, with a major lamp manufacturer, to evaluate the effect of phosphors on plastics, to allow for optimum selection of these phosphors in tubes to be used in conjunction with plastics. A long range program is being carried out by the lamp manufacturer in selecting glass envelopes which will prevent high emission of ultraviolet light. The net result of all these projects will be the increased usage of plastics in lighting, where, we in the plastics industry believe, they are ideally suited.

*See comments on Fig. 10.

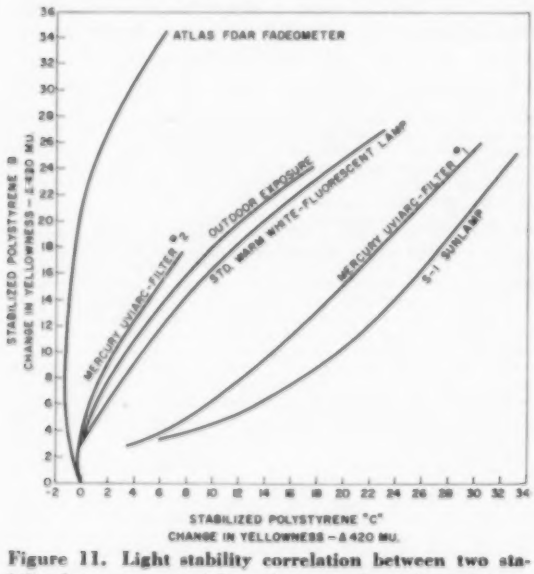

Figure 11. Light stability correlation between two stabilized styrene materials under several accelerated tests.

References

1. Orr, J. B.: "Discoloration of Polystyrene Shields; Its Cause and Solution," ILLUMINATING ENGINEERING, Vol. LII, No. 3, p. 136 (March 1957).
2. Property Specifications for Polystyrene Used in Fluorescent Luminaires," *Society of the Plastics Industry Bulletin*, p. 4, June 1957.
3. Ibid., p. 2.

DISCUSSION

G. R. BAUMGARTNER:* It would seem advisable to indicate the date of manufacture of the samples in Figs. 1 to 6.

While this paper deals principally with the color stabilization of styrene, I wish to congratulate the plastic industry not only for a fine job in the improvements they are making along these lines, but also for the techniques of molding, extruding, forming and finishing processes they continue to develop for the lighting industry.

With the higher levels which are evident it behooves today's lighting designers to incorporate some principles, if possible, which will increase the distance between lamps and styrene materials.

Some use of these methods is already in practice where semi-indirect and indirect lighting principles are employed. The plastic material making up most of the ceiling area is shielded from the lamps.

What form would the hypothetical stability line curve in Fig. 10 take if materials were unexposed to any light over a relatively long period of time?

H. A. WILLIAMS:** This is an interesting and informative paper which does much to clarify the behavior of polystyrene in fluorescent lighting applications. The problem of developing accelerated test methods for plastics has been one which has perplexed the plastics industry for a good many years. While a number of accelerated test methods have been used, the authors have clearly shown the limitations of many of such accelerated test methods and demonstrated the advantages of the "UViare" tests for styrene. Certainly, however, the behavior of plastics upon exposure to fluorescent light must be judged by the satisfactory field performance of that material in conventional lighting equipment over the years representing the useful life of the luminaire.

I would like to ask for clarification of several points.

(1) Would the authors explain why they defined yellowness in terms of change in reflectance at 420 millimicrons instead of calculating the yellowness factor by the procedure adopted by the IES-SPI-NEMA Subcommittee on Plastics for Lighting?

(2) Would the authors clarify what units are represented in the ordinates of Figs. 1 through 6 as there seems to be a change in wording between these figures, the definition of yellowness given and Fig. 8.

(3) In summarizing the data shown in Figs. 1 through 6, the authors state that such data were based on unstabilized polystyrene but that the performance of stabilized styrene can be estimated by using a factor of 2.5. Will the authors explain the basis for this statement?

(4) To compensate for the variability in lamp intensity, unstabilized samples of styrene were used as a control. How did the authors obtain assurance that there was no variability in the unstabilized polystyrene?

(5) If visual examination of the exposed samples used in preparing this report was made, will the authors comment on how closely this visual examination agreed with the mathematically obtained values?

Finally, I have a comment on the authors' statement that work is in progress by a lamp manufacturer on improved phosphors and glass envelopes to prevent high emission of ultraviolet light. The authors express the hope that this work will result in increased usage of plastics in lighting. I must point out that there are plastics, namely, the acrylics that, for over ten years, have given satisfactory service with the phosphors and glass envelopes used in existing fluorescent lamps.

R. S. HAWES, III:* I wish to congratulate Messrs. McCarthy and Popielski on the work they have done in regard to styrene. We feel this work is a forward step in gathering data on stabilized styrenes.

We believe there is one further avenue of approach to testing of plastic materials. Unfortunately our work on styrene is not quite completed.

Some time ago, at the recommendation of General Electric Co. at Nela Park, we started accelerated testing with a black light fluorescent lamp. We used a regular enclosed troffer luminaire with three 40-watt T12 black light lamps. Glass was used in the frame with the plastic attached to the glass on the lamp side. This is a very inexpensive test, easily set up by any fixture manufacturer. It is important to note that the black light does not emit wavelengths of energy not found in fluorescent lighting lamps. It has an energy peak at about 3500 angstroms. A degree of yellowing for comparative purposes can be obtained in about 150 hours. We have not correlated this in a definite manner, but within the next month, we will have finished actual exposure for two years, 24 hours a day, 7 days a week. This actual exposure was done with two different regular styrenes and two different stabilized styrenes.

In closing, we feel a great deal more data is needed on the subject of yellowing of plastic, and correlating present tests to actual exposure. From the testing we and others have done, together with field experience, we feel the present stabilized styrenes are excellent materials for lighting.

F. C. WINKLER:** As Chairman of the IES-SPI-NEMA Subcommittee which prepared and wrote "Property Specifications for Polystyrene Used in Fluorescent Luminaires" referred to by the authors on page 85, I feel it is my duty to prepare the following discussion.

When the spec was written and the Atlas Fadeometer selected for the specification test, there was concern on the part of some committee members that the tests were lacking in reproducibility, that correlation with actual exposure was doubtful and its accuracy for evaluating a wide range of products was questionable. On the other hand, we considered the fact that the test had stature as an ASTM method, the equipment was in use by several manufacturers for other testing — one manufacturer having over eight years of fluorescent lamp exposure data on polystyrene to back up its Fadeometer data — plus other advantages such as: (a) wide availability; (b) quality and intensity of the source is constant; (c) energy of source is sufficient but not excessive for accelerated testing; (d) energy of source in the significant range more closely approximates the energy distribution of the fluorescent lamp; (e) no radiation below 300 millimicrons; (f) the fact that the Fadeometer energy is deficient in the visible range is immaterial.

These and other considerations, such as the fact that tests by other methods by the critics of the Fadeometer were both lacking and inconclusive, caused us to agree to accept the Fadeometer and this is so indicated in our standard.

This paper, on the other hand, certainly shows that the authors have investigated and assessed several accelerated

*General Electric Co., Cleveland, Ohio.
**Rohm and Haas Corp., Philadelphia, Pa.

*K-S-H Plastics, Inc., High Ridge, Mo.
**Westinghouse Electric Corp., Cleveland, Ohio.

exposure tests simulating long-term exposure to fluorescent lamps. Their paper states that the method they used, namely, the UViare with suitable filters, duplicates and accelerates exposure to fluorescent lamps; is not dependent for correlation on any type of stabilizing system; and is superior in this regard to other testing methods studied. In this connection, I would like to pose several questions.

Since it is a well known fact that an ultraviolet absorbing chemical added to polystyrene produces no stabilizing action to the polymer above its ultraviolet cut-off (the ultraviolet cut-off point is the wavelength below which there is no significant transmission of impinging radiation), why is it necessary and important that the wavelength of the light source (test source) must closely duplicate fluorescent light emissions in order that extrapolation of short term testing results to estimate maximum useful life be possible? A comparison of Figs. 9a and 9d shows no significant improved matching by the UViare.

I note also that the UViare emits only the mercury lines and is therefore not a continuous spectrum. Thus, matching only the peaks in the fluorescent spectrum and then claiming that this yields results that are reliable seems questionable to me.

The UViare test method described in this paper shows good utility in the evaluation of the ultraviolet light stabilizing system with which they have worked. I feel that this is brought out quite clearly and certainly is technically sound, but unfortunately, it gives one the impression that the UViare method should be used in the evaluation of *all* types of stabilizing systems for polystyrene. Specifically, the method described may be suitable for the evaluation of polystyrene containing *ultraviolet absorbers*, but I am not convinced that it can be equally well adapted for the evaluation of all types of stabilization systems for polystyrene used in fluorescent luminaires.

In our IES-SPI-NEMA polystyrene spec, we show various yellowness factors with limiting values. According to this paper, how would the authors express them?

I would like to know why no mention was made in the paper and no charts or graphs shown of the effects of continuous fluorescent exposure on the yellowness factor of the ultraviolet stabilized polystyrene they used in their work. In other words, there is no mention of the total useful life of this particular polystyrene compound under continuous fluorescent exposure up to a predetermined level of yellowness as shown in our standard.

On page 87 under "Actual Exposure to Fluorescent Lamps," I find two statements as follows: (a) "Significant information for judgment was obtained after 1500 hours and (b) Discoloration rates are relatively slow by this method and long term aging data require at least 10,000 hours or 14 months of continuous exposure."

In view of these two statements I wonder if the 1500 hours is a typographical error or whether the authors really mean that judgment could actually be made in that time, realizing that 1500 hours is only equivalent to 62 days.

I believe this work reopens the question of an economical, rapid and correlatable test for the evaluation of plastics for use in fluorescent luminaires. It is therefore hoped that the authors and others will submit more data now available, or at present being taken by various other methods such as the Bush Xenotest Light Fading Tester, the General Electric Fluorescent Black Light Lamp Test and others, so that the most accurate and/or most practical method of specification testing can be determined for consideration by the Illuminating Engineering Society.

May I congratulate the authors on a pertinent and practical paper, which, incidentally, is one of the first I have seen on this subject. More work of this nature can be of great significance to the lighting industry and to every one of us.

D. A. POPIELSKI AND R. A. MCCARTHY:* In reply to Mr. Baumgartner's questions, we would like to say that the date of manufacture of the samples shown in Figs. 1-6 of the paper was March 1957, and the evaluations were started during the same month. In regard to the yellowing expected in general purpose styrene samples, unexposed to any light over a relatively long period of time, we regret that we have no long term "dark room" exposure data since we have little call for this information. We recognize that yellowing does take place in general purpose styrene over a period of time even when not exposed to light. Efforts to reduce the natural yellowing rate due to oxidation have continued over the years, so that current products are less susceptible.

We do know the general purpose polystyrene in a pelleted form has been stored for at least eighteen months at abnormally high temperatures and subsequently molded into a finished product with no objectionable increase in yellowness as compared to newly produced material, as measured by visual comparison. On the other hand, a difference in yellowness between old and new unexposed samples can be picked up by a spectrophotometer in approximately 10 months. We believe the additives found in "Lustrex perma tone" would reduce this "unexposed" natural yellowing and so show additional color stability as compared to unstabilized styrene.

In answer to the questions raised by Mr. Williams, the reason for using the change in reflectance at 420 mμ rather than the IES-SPI-NEMA yellowness which requires transmission data is that the latter procedure allows no provision to be made as to whether the incident light strikes a yellowed (exposed) surface or the unexposed surface. This will obviously affect both visual and instrumental results. The greater visual differences are observed by reflection against a white background with the exposed surface of the same face-up. Fig. 8 graphically shows that the change in reflectance between the exposed and unexposed samples is a maximum of 420 mμ, indicating a high loss in the blue end of the spectrum. An analysis of the spectral curves in Fig. 8 shows no change at 680 mμ and hence, while the numerical results differ from the IES SPI-NEMA yellowness procedure, there is no major conflict between the results obtained by either procedure. Δ 420 units can be roughly converted to IES-SPI-NEMA units by multiplying by 0.75.

Figs. 1-6 should have had "Change in Reflectance at 420 mμ" as the ordinate instead of "Change in Yellowness at 420 mμ."

In regard to using a figure of 2.5 as a comparison of performance of unstabilized polystyrene and stabilized polystyrene, we believe that this is an average figure since the improvements noted range from 2.2 to 3.2 depending on the fluorescent light source.

As to procedures used to assure there was no variability in unstabilized polystyrene used as control samples, we used one commercial lot of a styrene for testing. Spectral data were taken on all molded samples as made and no variations between samples were found.

In regard to how close the visual examinations agree with mathematically obtained values, it can be stated that visual ranking and instrumental ranking of yellowness gave a 100 per cent correlation because of the nature of the

*Authors.

yellowing (see Fig. 8), and the fact that the same color samples were used throughout.

We are in agreement with Mr. Hawes that the General Electric black light offers a good inexpensive accelerated test. However, we believe that additional information is required to determine its effect on stabilizing systems other than the commercially available stabilized styrenes as well as its effect in duplicating physical property degradation caused by exposure to fluorescent light.

Mr. Winkler questioned why it was necessary that the wave length of the testing light source closely duplicate fluorescent light emission in order that short term test results could be used to estimate maximum use life. He pointed out the comparison of Figs. 9a and 9d showed no significant improved matching by the UViare. However, Figs. 9a-9d are shown on a relative energy basis only. On an absolute basis, the Fadeometer's emission at 3850 Angstroms is three times greater than any part of the solar energy spectrum (as measured in Washington, D.C. at noon in June). We know that the discoloration rate of polystyrene increases rapidly with a decrease in wave length of radiation. The 3650 band is roughly only one-fifteenth as aggressive to styrene as the 3100 Angstrom band. Since polystyrene has even less absorption at 3850 Angstrom than at 3650 Angstrom, this means that the discoloration due to Fadeometer exposure is not due to the bulk of its emitted energy but rather to its lower amounts of shorter wave length emissions.

The performance of these various test methods in Fig. 10 cannot be explained simply by comparing spectral energy curves. However, in lieu of closely duplicating fluorescent light emissions, we are attempting to obtain a combination of ultraviolet light emissions from 3000 Angstrom to 3650 Angstrom which will duplicate the *effect* of the fluorescent light emission. While we discount the Fadeometer, because the bulk of its emissions fall in a region where polystyrene has very little absorption, it is still a valuable tool for testing fastness of pigments and dyestuffs which are affected equally by ultraviolet and visible radiations.

In regard to UViare emitting only mercury lines and not a continuous spectrum, it is our understanding that fluorescent lamps contain mercury and hence emit mercury lines as denoted in Figs. 9a-9d. The continuous spectrum of the fluorescent lamp, which is due to the phosphor coating inside the tube, is generally the only part of the spectrum given in brochures by lamp manufacturers. (Note that the S-1 Sunlamp and UViare, which are mercury lamps, show these same line spectra.)

In regard to the value of the UViare for various types of stabilizing systems as well as the ultraviolet light absorbing systems covered by this paper, we can say that it would be surprising if the UViare is equally effective on all types of stabilizing systems, since the method is an attempt to duplicate *effect* rather than a duplication of spectral energy. Methods of stabilizing polystyrene have not been exhausted, and it is even conceivable that some future stabilized polymer might have phototropic stability, in which case, any continuous exposure method (even under fluorescent light) would not be indicative of its performance under discontinuous lighting.

Answers to Mr. Winkler's fourth and fifth questions will be found in our rebuttal to Mr. Williams' discussion.

Significant information for judgment based on exposure to fluorescent lights can be obtained after 1500 hours using deluxe warm white fluorescent lamp at a plastic-to-lamp distance of ½ to 1 inch. The reference to standard cool white lamps in the paper was incorrect. Longer term aging is required for more discriminating judgment.

More Approved Illumination Levels

The illumination levels for the areas designated below, determined by IES Technical Committees, have been approved for the *IES Lighting Handbook* by the Council of the Illuminating Engineering Society.

CHURCHES AND SYNAGOGUES	Currently Recommended Illumination* Footcandles
Altar, ark, reredos	100**
Choir*** and chancel	30**
Classrooms	30
Pulpit, rostrum (supplementary illumination)	50**
Main worship area***	
Light and medium interior finishes	15**
For churches with special zeal	30***
Art glass windows (test recommended)	
Light color	50
Medium color	100
Dark color	500
Especially dense windows	1000

*Minimum on the task at any time.

**Two-thirds this value if interior finishes are dark (less than 10 per cent reflectance) to avoid high brightness ratios, such as between hymnbook pages and the surround. Careful brightness planning is essential for good design.

***Reduced or dimmed during sermon, prelude or meditation.

SCHOOLS	Currently Recommended Illumination* Footcandles
Reading printed material	30
Reading pencil writing	70
Spirit duplicated material	
Good	30
Poor	100
Drafting, benchwork	100**
Lip reading, chalkboards, sewing	150**

*Minimum on the task at any time.

**Obtained with a combination of general lighting plus specialized supplementary lighting. Care should be taken to keep within the recommended brightness ratios. These seeing tasks generally involve the discrimination of fine detail for long periods of time under conditions of poor contrast. To provide the required illumination, a combination of the general lighting indicated plus specialized supplementary lighting is necessary. The design and installation of the combination system must provide not only a sufficient amount of light but also the proper direction of light, diffusion and eye protection. As far as possible it should eliminate direct and reflected glare as well as objectionable shadows.

The Two Faces of Lighting a

- Adequate levels and, above all, proper color of light and surroundings to aid the beauty parlor operator.

- Luxurious and relaxing environment to make the customer feel glamorous — and beautiful.

Burdine's Department Store Beauty Salon, Miami, Florida. The dropped ceiling area in the foreground (above) is lighted by 150-watt inside frosted lamps in recessed louvered downlights and 40-watt fluorescent lamps in luminous panels. General lighting in the working area is from 150-watt silvered bowl lamps in recessed units spaced 6 feet by 7 feet. Cove at the right is equipped with a double row of deluxe 40-watt fluorescent lamps. The luminous decorated panels in the partition are lighted from behind with three rows of 20-watt fluorescent lamps, one across the top, one across the center and one at the bottom. Another view of the same salon (below) shows custom-designed architectural element over the basins and dryers, with two rows of 40-watt fluorescent lamps above glass panels, on both sides of the partition.

BEAUTY is said to be in the eye of the beholder, but there is a lot more to it than that. Beauty parlor operators experience, constantly, the problems of color of light, reflectances of skin and hair, and various combinations of light and pigmentation. In one booth, blonde hair will be reflecting about 60 per cent of the light, and in the next booth, under the same light source, brown hair will reflect only 10 per cent.

And beauty parlor managers know that a glamorous and pleasant environment is, in part, what brings patrons back for a repeat performance.

These two practical considerations affect the choice of lighting systems — both sources and the luminaires. Particularly for the work done in beauty parlors, however, the *color* of the light is important. Hair coloring is now an accepted and widely-used cosmetic and the lighting under which it is applied determines its success.

The sources most frequently used are incandescent, in direct, indirect and general diffusing equipment, and fluorescent, in direct and direct-indirect units. Incandescent lamps produce light that is rich in red and deficient in blue. This color emphasizes the warmer hues and creates a psychologically warm atmosphere. But incandescent lighting at levels of over 25 footcandles tends to contribute undesirable heat to the area. The higher levels required today have caused a move to fluo-

Photos and data courtesy of James F. Finn, Detroit Edison Co., Detroit, Mich.

Beauty Parlor

J. L. Hudson Co. Beauty Salon, Detroit, Michigan. Recessed reflector units with concentric ring louvers and 200-watt incandescent lamps are mounted over the hair styling chairs. Additional illumination is provided by deluxe cool white fluorescent lamps in the overhead cove.

rescent sources in deluxe colors, combined with incandescent to create a pleasing environment.

It is recommended that if louvered luminaires are used 45-degree shielding parallel to the line of sight and 35- to 45-degree perpendicular to the line of sight be provided. At these limiting angles the maximum average brightness should not exceed 750 footlamberts. Brightness of luminous luminaires, recessed, ceiling-mounted, suspended or wall-to-wall ceilings, should not exceed 750 footlamberts average brightness. Many manufacturers specify brightness of their units in their catalogs. Suggested mounting heights for luminaires are:

Ceiling Height	12 Feet	11 Feet	10 Feet	8 Feet
Mounting Height	10 Feet	9½ Feet	9 Feet	7½ Feet

Pendant suspended fixtures provide up to 25 per cent more light after approximately a year's service than do ceiling mounted units without maintenance. Self-ventilating features of suspended fixtures minimize dirt collection.

Caution should be exercised in the selection of fixtures for ceiling mounting. The National Electrical Code, 1956 Edition, specifies the following: "Fixtures having exposed ballasts or transformers shall be so installed that such ballasts or transformers shall not be in contact with combustible material. Where fixtures are to be installed on combustible low-density cellulose fiberboard, the fixtures shall be approved for this condition or they shall be mounted not less than 1½ inches from the surface of the fiberboard."

Troffers and other recessed lighting should be

Nieman Marcus Beauty Salon, Dallas, Texas. Recessed in the ceiling over the counter is a continuous row of two-lamp glass-covered fluorescent fixtures with deluxe warm white lamps. Recessed spots are 150-watt elliptical downlights. Indirect illumination is supplied by a row of fluorescent lamps behind the mirror top and a fluorescent cove (which can be seen in the mirror). Ceiling height is 8 feet 10 inches. Emphasis is on warm fluorescent lamps and incandescent, to provide an environment similar to that of a home.

The Glamour Nook Beauty Salon, Detroit, Michigan. Color scheme in this salon is correlated with the lighting to provide the two requirements of beauty parlor lighting: proper color and level of light and glamorous and restful atmosphere. Ceiling of off-white acoustical tile is dropped over the styling booths, with a continuous row of shielded fluorescent lamps centered over the chair backs to illuminate the hair. All upholstery, except in the reception area, is coral and walls are light green. Counter tops are marbleized gray and pink. Opposite the styling booths and behind the cloak room is the styling bar, which utilizes the predominant red-yellow cast of incandescent lighting to flatter skin and hair tones. This shop also features ultraviolet lamps to handle unpleasant odors of chemicals and smoke.

carefully designed for good distribution and low brightness with close spacing of fixtures to minimize contrast between fixture and ceiling brightnesses. Possible monotony of large luminous ceiling areas can be avoided by acoustical wedge baffles, which can also house a sprinkler system — and lower the decibel level of inevitable chatter.

Levels of illumination suggested are: hair cutting, 100+ footcandles; color matching and hair styling, up to 150+ footcandles. Somewhat lower levels are desirable in circulation and sitting room areas, for a change of pace. Ratio of levels between working areas and sitting areas should not exceed 5 to 1.

The place where the patron stands or sits, rather than the mirror, should be illuminated. Vertical placement of sources concealed in coves on either side of the mirror can provide a flattering light without direct glare.

Matte finishes are recommended for walls and ceilings, both for lighting purposes and for appearance. Reflectances should be: ceilings, 75 to 85 per cent; floors, 25 to 35 per cent; walls 35 to 55 per cent. Colors should be chosen to fit cosmetic and hair dressing needs, since as lighting levels are increased there is more reflected light from side walls, ceiling and other objects.

People are emotionally responsive to their surroundings. Warm-colored surfaces appear to advance toward the observer and make a room seem smaller. Conversely, cool colors appear to recede and can be used to increase the apparent size of the room. These factors and the color of the light in a beauty parlor are what must be balanced to produce a luxuriously attractive and relaxing environment for the customer and adequate — both as to color and level — functional illumination for the working operator.

New IES Recommended Levels of Illumination — how they were determined, what they are. Reprints of the August 1958 IE feature on this important subject for those areas then determined* are still available (latest printing makes a total of 25,000 copies distribution). Twenty cents each in any quantity. Order from Publications Office, Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

*See page 91 for new recommendations for Churches and Synagogues and for Schools.

Setting for Beauty

OF GREAT importance in planning the lighting layout for a beauty parlor (see page 92) is the placement of light to provide, in addition to color and sparkle, the modeling effects essential to successful hair styling and customer satisfaction. When a woman leaves a beauty parlor, she expects to look her best, and the lighting for such an establishment must be engineered to foster that effect.

A single light source directly above the work area creates harsh shadows in front of the face, and prevents the customer from getting the most complimentary view of her face and hair when she looks in the mirror. In the installation shown above, 300-watt silver-bowl lamps in two-foot square metal louvered recessed units have been arranged in the pattern of a "five," as seen on the face of dice, to provide suitable directional light for a modeling effect, in addition to the soft shadows flattering to the face. This basic design, engineered for a 32- by 52-foot store with a ten-foot ceiling, results in 45 footcandles maintained illumination level.

The owner of this shop, realizing the value of good lighting in increasing customer satisfaction, called on a lighting engineer when he decided to remodel his shop. First came the job of discouraging the owner from putting in an all black floor —a white and black patterned tile floor, two-thirds white and one-third black, was finally agreed upon. Surfaces were painted in light colors: white dressing stations, white ceilings and light violet and grey walls. This color scheme, aside from increasing the interreflections of light within the room, serves to encourage better housekeeping by the ten beauticians employed in the shop, and provides suitable color rendition of the reflected light.

The ceiling in this beauty salon was planned to be, as most ceilings are, chock full of steel joists, sheet metal ducts, music system components and electrical wiring. The lighting design was planned to fit into the network of steel joists placed on four-foot centers. This arrangement also allowed line runs of heating and cooling duct work to branch out from the wall to various outlets in the room.

Keeping to the "five" pattern, the fixtures were placed so that three sources illuminated each station from approximately equal angles, creating soft shadows and the directional quality desired. All fixtures are wired and switched to accommodate 500-watt silver-bowl lamps, where desired, instead of the 300-watt lamps originally installed.

In the hair-washing areas, supplementary illumination is supplied by a 75-watt R30 floodlamp housed in a wall-mounted bullet unit at each station. Sufficient illumination in the drying areas allows the customers to read in comfort while seated under the dryers.

With the installation of this lighting system and the accompanying changes in the surroundings, this Milwaukee beauty shop is able to serve its customers in a professionally designed, advantageous atmosphere.

George E. Dolan, Wisconsin Electric Power Co., Milwaukee, Wis., engineered this installation which won second prize in the Milwaukee Section's 1958 My Most Interesting Lighting Job contest.

Self-Ballasted Vapor Lamps—

New Basic Design Data and New Improved Types

By HERBERT S. STRAUSS
WOLFGANG E. THOURET

All three familiar elements of electrical light production, an incandescent filament, a phosphor and a high pressure mercury arc tube, can be combined into one compact self-contained unit — the self-ballasted fluorescent-incandescent-mercury lamp. This new light source has certain useful characteristics not found together in any of the other three widely-used types of electrical lamps. New quantitative data are presented as a basis for optimum designs and for a discussion of the possibilities and limitations of self-ballasted lamps. The characteristics of two new experimental types of 450 watts and 1750 watts are described.

THE INCANDESCENT - fluorescent - mercury vapor self-ballasted lamp utilizes all three fundamental physical effects of electrical light production in one self-contained unit. It it a well-balanced combination of three familiar elements: an incandescent filament, a mercury vapor quartz arc tube, and a fluorescent substance converting ultraviolet into visible radiation. But it actually represents a fourth light source with certain useful and advantageous characteristics which cannot be found together in any of the other three lamp types.

Self-ballasted mercury lamps or combination lamps or triple-source lamps, as they are sometimes called, are compact units like incandescent or mercury vapor lamps. They have undelayed light output when switched on, and they do not require an external ballast. Their life is much longer than that of incandescent lamps and similar to that of mercury vapor and fluorescent lamps. Their luminous efficiency is much higher than that of filament lamps but lower than the efficiency of mercury vapor and fluorescent sources. Their red color rendition can be similar to daylight and has a certain degree of flexibility.

Since 1940, self-ballasted mercury vapor lamps without phosphor have been developed and are in use in several European countries. They evolved mainly from the practice of adding considerable numbers of incandescent lamps to mercury vapor installations, indoors and outdoors, in order to achieve satisfactory color quality. It was found very convenient to combine mercury arc tube and incandescent filament into one lamp that fits standard fixtures and sockets, using the filament as ballast for the vapor discharge and thus saving the otherwise required external ballast.

However, the use of these European combination lamps has been limited and they have found no interest in this country because of their rather low efficiency of around 18 lumens per watt and their rather short rated life of 2000 or 3000 hours. The reason for these unfavorable features is that these lamps, in order to achieve a satisfactory red color rendition similar to daylight, have been designed on the basis of an approximate 1:1 lumen ratio.[1,2] This means that the wattages of mercury burner and incandescent filament are adjusted to a relation that results in nearly equal lumen output of both light-producing elements. As the luminous efficiency of the mercury arc tube amounts to three or four times that of the filament, the result is that only a small part of the total lamp wattage can be allotted to the efficient mercury vapor discharge. Consequently, the overall luminous efficiency is only slightly higher than that of equal wattage incandescent lamps. The rated life is rather short because it depends upon the life of the filament, and this has to be limited in order to prevent further losses in efficiency.

This paper reports on the development of greatly improved new types of self-ballasted lamps with an efficiency of 29 to 34 lumens per watt and the long life of mercury vapor lamps (7000 hours or more), in addition to the improved-color quality and the other favorable features of the earlier European lamps. These improvements are mainly based on the use of the so-called high temperature phosphors that have become available since 1950.[3-6] In the

A paper presented at the National Technical Conference of the Illuminating Engineering Society, August 17-22, 1958, Toronto, Ont.
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This paper accepted by the Papers Committee of I.E.S. as a Transaction of the Illuminating Engineering Society.

first part of the paper, basic design data for self-ballasted lamps are presented in order to give a complete picture of their possibilities and limitations. The second part will describe the characteristics of some practical lamp types.

Basic Design Data

The main problem arising in connection with the design of self-ballasted lamps is how the total lamp wattage is to be distributed between the mercury vapor discharge tube and the incandescent filament. In order to achieve an optimum overall luminous efficiency, it is, of course, desirable to make the ratio between arc tube wattage and filament wattage as great as possible. Two factors have to be observed in determining this ratio: (1) the desire to achieve a satisfactory color rendition, *i.e.* a sufficient amount of red light output, and (2) the necessity of reliable arc tube operation even under great fluctuations in the supply voltage.

Satisfactory Color Rendition and Red Proportion. The only accurate basis for judging the color rendition of a light source is, of course, its spectral energy distribution. However, in the field of mercury vapor and related light sources, where the output of red light is of particular importance, it has become customary to use the so-called "red proportion" as an approximate measure of color quality.[7-9] Red proportion is the percentage of the total lumens that can be measured through a certain red filter tranmitting mainly the two red spectral bands (610-660mμ and 660-760mμ as defined by C.I.E. standard.[10] It provides an index that conveniently characterizes the approximate color rendition of a lamp in the red part of the spectrum.

Fig. 1 shows the transmittance curve of the Corning filter No. 2418 CS 2-62 that was used for the measurements reported in this paper. All red proportion values were corrected for the absorption of the filter itself by determining its absorption factor for every light source measured. Considerable variations in transmittance between individual filters of the same type and color specification were found. Differences in the measured red proportion of a given lamp amounted to as much as 1.5 per cent. Therefore, when different filters are used, tolerances of about ±0.8 per cent apply to the red proportion values. Much greater variations result with different filter types.

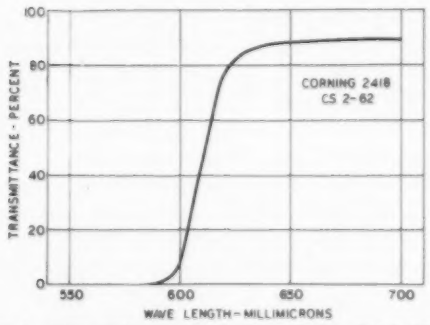

Figure 1. Transmittance of Corning Filter 2418 CS 2-62 used for red proportion measurements.

TABLE I — Red Proportion Values of Several Light Sources.

Source	Efficiency Lumens/Watt	Approximate Red Proportion %
Single coil tungsten filament (similar to 1000-watt 230-volt gas filled lamp)	5.3	33.7
	9.4	31.2
	11.7	30.7
	13.9	30.3
	16.3	29.4
400-watt E-H1 Mercury Vapor Lamp	46.7*	1.7
400-watt J-H1 Mercury Vapor Lamp (magnesium-fluorogermanate phosphor)	45.6*	8.7
400-watt S-H1 Mercury Vapor Lamp (strontium-zinc-phosphate phosphor)	51.2*	5.5
Standard Illuminant C	—	13.1

*Average ballast losses included in wattage consumed.

For comparison, Table I contains the red proportion values as defined above for several well-known light sources including Standard Illuminant C, which approximates daylight as provided by a combination of direct sun and clear sky light (color temperature approximately 6500K). These red proportion values are in conformity with the well-known facts that between 11 and 14 per cent red are required in order to achieve daylight similarity of a light source, that incandescent lamps have an excessively high, and regular mercury vapor lamps a very low amount of red light. Improved-color mercury lamps with magnesium-fluorogermanate phosphor are greatly improved in their red proportion, but do not attain daylight quality.

The color rendition of self-ballasted lamps is considered satisfactory with an overall red proportion of around 12 per cent. In order to find the arc tube/filament wattage ratio that makes this red content possible, the corresponding lumen ratio must be determined. With a given red proportion r_f of the filament and a combined red proportion r_{aph} of mercury arc tube plus phosphor, the arc tube/filament lumen ratio

$$\frac{L_a}{L_f} = \frac{r_f - r_{tot}}{r_{tot} - r_{aph}} \qquad (1)$$

is required in order to achieve a desired total lumen red content r_{tot}.

The curves of Fig. 2 are based on Equation (1) and illustrate the decisive influence of r_{aph}, the amount of red radiation available from the arc

tube-phosphor combination, on the required lumen ratio between arc tube and filament L_a/L_f. They show why self-ballasted lamps without phosphor, like those of earlier European design, have to be based on an approximate 1:1 lumen ratio, if a total red proportion of 12 per cent is desired. Much more favorable lumen ratios, from 5:1 to 10:1, are possible without reducing the color quality under 11 per cent red, if r_{aph} is increased from 1.5 per cent to 8 or 9 per cent by means of a phosphor. Fig. 2 further demonstrates that a total red content of nearly 8 per cent is obtainable with phosphors of limited red emission that increase the arc tube red proportion only approximately to $r_{aph} = 5.5$. Self-ballasted lamps without phosphor can be designed with total red proportions up to 5 per cent and with lumen ratios greater than $L_a/L_f = 5:1$, which lead to total lamp efficiencies above 30 lumen/watt.

The Fig. 2 curves have been calculated with a constant red proportion $r_f = 30$ per cent. According to Table I, this value applies with small variations to all tungsten filament operating conditions that are practical in self-ballasting lamps. Some authors[1,2] have arrived at a filament red proportion of 25 per cent, probably because they use a different filter type and do not correct for the filter absorption.

The arc tube/filament wattage ratio W_a/W_f can be derived from the lumen ratio according to

$$\frac{W_a}{W_f} = \frac{L_a}{L_f} \cdot E_r \qquad (2)$$

with E_r designating the ratio between filament and arc tube efficiencies. The efficiency of mercury vapor arc tubes with different characteristics varies only within relatively narrow limits. The efficiency ratio E_r is thus mainly determined by the rated life of the filament.

Equation (1) and the curves of Fig. 2 can only supply an approximation for the lumen ratio L_a/L_f. The exact lumen ratio that can be realized in a lamp depends upon several other parameters besides the red proportion values. The more influential of these are rated lamp life, rated number of starts and the extinguishing voltage of the arc tube.

Experimental results have confirmed the above theoretical considerations. Figs. 3 to 8 present the data obtained from test lamps made with different arc tube/filament wattage ratios under variation of several other parameters. Self-ballasted lamps of constant overall wattage and designed for a given supply voltage were equipped with mercury arc tubes of varied operating pressures and voltages. The ballast filaments were adjusted to every arc tube in order to consume the exact difference between total lamp wattage and individual arc tube wattage. The filament operating temperatures were held constant within narrow limits in order to prevent variations in efficiency.

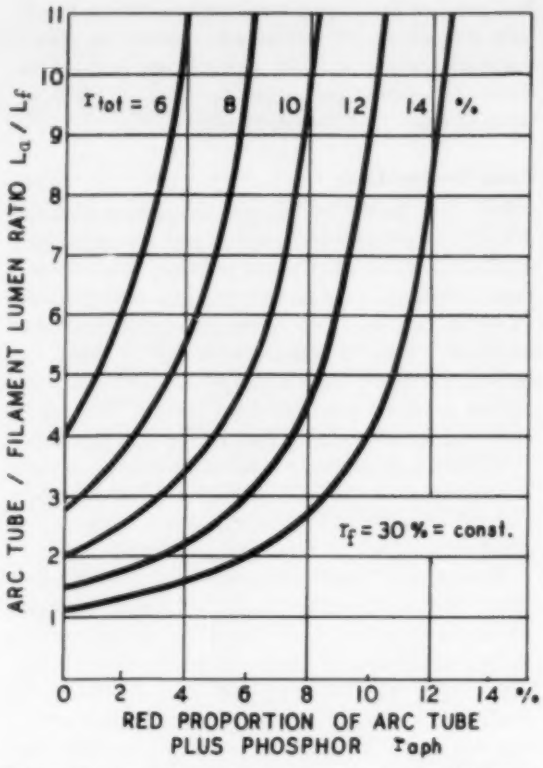
ARC TUBE / FILAMENT LUMEN RATIO L_a / L_f
r_{tot} = 6
8
10
12
14 %
r_f = 30 % = const.
RED PROPORTION OF ARC TUBE PLUS PHOSPHOR r_{aph}
0 2 4 6 8 10 12 14 %
1 2 3 4 5 6 7 8 9 10 11

Figure 2. Arc tube/filament lumen ratio for different requirements of total lumen red proportion (r_{tot}) as a function of red proportion of mercury plus phosphor radiation (r_{aph}). Filament red proportion $r_f = 30$ per cent = constant.

In Fig. 3 we find the lumen output and the total red proportion of 750-watt, 230-volt lamps in R-57 bulbs with magnesium-fluorogermanate phosphor as a function of the arc tube/filament wattage ratio. Besides the total lumens, the lumen contributions of the arc tube and the filament alone — both when operated in the phosphor-coated bulb — are shown. As expected, the over-all luminous efficiency increases considerably with growing arc tube/filament wattage ratio. The overall red proportion decreases but remains virtually constant and above 10.5 per cent at greater wattage ratios. It is thus established that, from the point of view of satisfactory color and luminous efficiency, the highest possible wattage ratio should be chosen for self-ballasted lamps. The upper limit of the wattage ratio is determined by the highest extinguishing voltage of the arc tube that is compatible with reliable lamp operation, as will be discussed later.

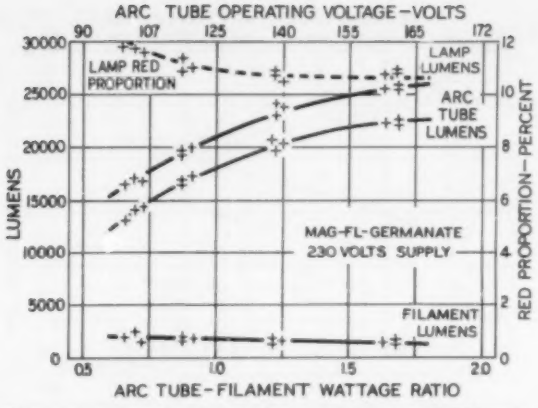

Figure 3. Lumen output and red proportion of 750-watt self-ballasted lamps as a function of arc tube/filament wattage ratio, showing contributions of the component light sources. Supply voltage, 230 volts. Magnesium-fluorogermanate phosphor, R-57 bulb.

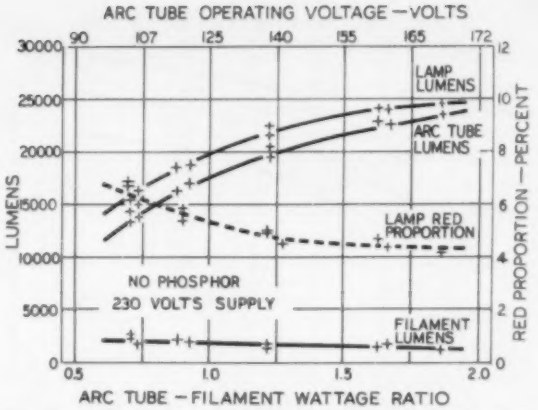

Figure 4. Lumen output and red proportion of 750-watt self-ballasted lamps as a function of arc tube/filament wattage ratio, showing contributions of the component light sources. Supply voltage, 230 volts, no phosphor, R-57 bulb.

Fig. 4 shows the same measurements taken with the same series of test lamps as in Fig. 3, the only difference being that no phosphor was used on the outer bulb. The filament lumens are virtually unchanged, indicating that the phosphor does not absorb an essential amount of the visible filament radiation. The red proportion values are greatly reduced, as expected. The arc tube lumens and the total lumens are slightly lower than in the lamps with phosphor. An explanation for this can be seen in the fact that in the self-ballasted lamp the magnesium-fluorogermanate phosphor operates at a higher temperature than it does in the usual improved-color mercury vapor lamp. This is more favorable to its emission properties, and thus it contributes more to the overall lumen output.[3,4] The higher bulb temperature results partly from the greater total wattage consumed in a given bulb and partly from the greater amount of infrared heating energy that is supplied by the filament.

Fig. 5 contains the results obtained when measuring the same test lamp series as in Figs. 3 and 4 with strontium-zinc-phosphate-phosphor on the outer bulb. The red proportion is considerably reduced, arc tube lumens and total lumens are increased above the values found with magnesium-fluorogermanate, as anticipated.

In order to show the influence of variations in total wattage and bulb size and shape, data for 450-watt, 230-volt test lamps in BT-37 bulb are given

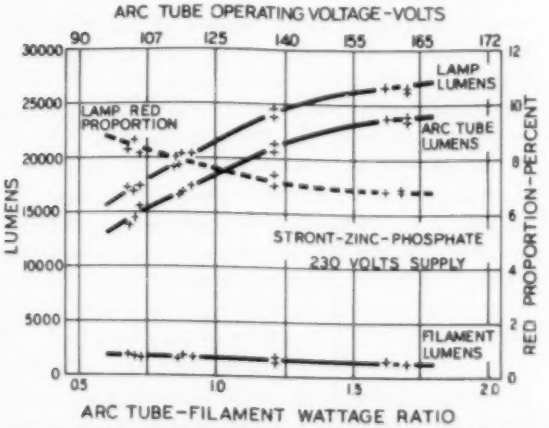

Figure 5. Lumen output and red proportion of 750-watt self-ballasted lamps as a function of arc tube/filament wattage ratio, showing contributions of the component light sources. Supply voltage, 230 volts, strontium-zinc-phosphate phosphor, R-57 bulb.

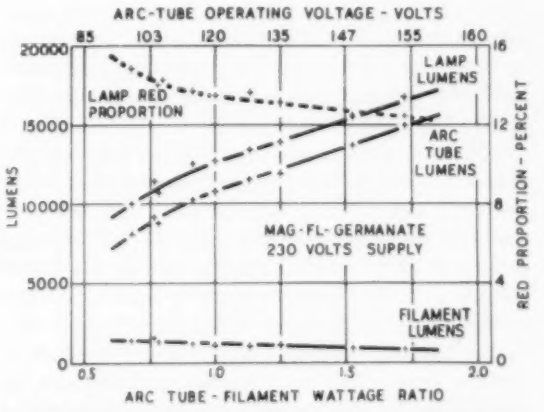

Figure 6. Lumen output and red proportion of 450-watt self-ballasted lamps as a function of arc tube/filament wattage ratio, showing contributions of the component light sources. Supply voltage, 230 volts, magnesium-fluorogermanate phosphor, BT-37 bulb.

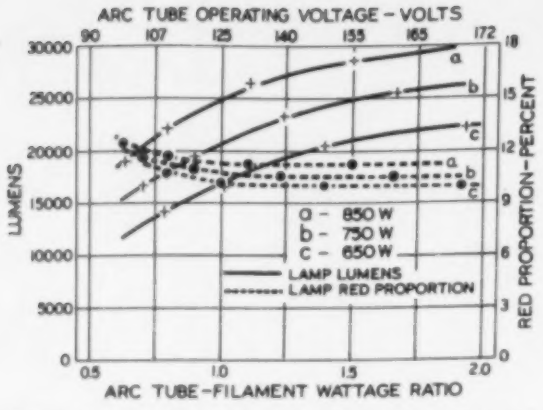

Figure 7. Total lumen output and red proportion of 750-watt self-ballasted lamps as a function of arc tube/filament wattage ratio, showing the influence of variations in wattage. 230-volt supply voltage, magnesium-fluorogermanate phosphor, R-57 bulb.

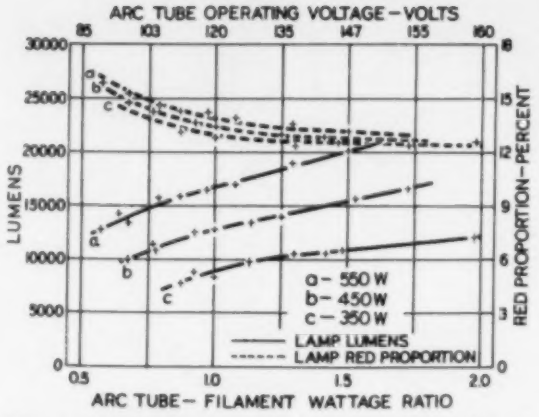

Figure 8. Total lumen output and red proportion of 450-watt self-ballasted lamps as a function of arc tube/filament wattage ratio, showing the influence of variations in wattage. 230-volt supply voltage, magnesium-fluorogermanate phosphor, BT-37 bulb.

in Fig. 6. They are similar to those of the 750-watt lamps, except that the red proportion values are considerably higher. This may be due to the fact that the BT-37 bulb is fully covered with phosphor, while the R-57 reflector type bulb used for the 750-watt lamps is only partly coated.

Figs. 7 and 8 show the total lumen output and red proportion as a function of the arc tube/filament ratio under the influence of variations in total wattage. The data given in Figs. 3 to 8 all refer to lamps designed for 230-volt power supply systems. Similar curves would result from test lamps for supply voltages of 277, 208 and 120/130 volts. Self-ballasted lamps for 120 volts have somewhat lower efficiencies than the lamps for the higher voltage ranges because of the reduced efficiency of mercury vapor arc tubes with lower operating voltage. 120-volt self-ballasted lamps must be equipped with special arc tubes having automatically pre-heated electrodes in order to reduce the ignition voltage sufficiently.

Arc tube extinguishing voltage. It has been explained, in detail, that great wattage ratios between arc tube and filament are desirable for optimum performance self-ballasted lamps. High wattage ratios are attained with high arc tube operating voltage and these reach an upper limit when the corresponding extinguishing voltage of the arc tube under given operating conditions approaches a certain limit. The extinguishing voltage can be determined by quickly reducing the voltage of the power supply and observing the voltage at which the arc tube extinguishes. This voltage is much higher than the arc tube operating voltage because of the existence of the reignition peak. The extinguishing voltage of a given arc tube is higher with resistor ballast than with inductive ballast. It is further influenced by voltage and frequency of the power supply and operating current.

The allowable upper limit for the extinguishing voltage is determined by the greatest temporary decrease in supply voltage under which the lamp shall continue to operate. Experience has shown that voltage reductions in power supplies of more than 18 per cent of nominal value are very rare and that operational reliability of self-ballasted lamps can be assumed if the arc tube extinguishing voltage is kept below this figure. Allowance has to be made, of course, for possible increases of the extinguishing voltage during arc tube life.

According to the above figure of 18 per cent voltage reduction of power supply, the arc tube extinguishing voltage must remain under 170 volts for 208-volt supplies, under 188 volts for 230-volt, and under 98 volts for 120-volt supplies. Fig. 9 shows the extinguishing voltage of 400-watt mercury arc tubes of different operating voltages for operating currents between 2.5 and 4.0 amperes and for 208- and 230-volt 60-cycle power supplies. These data allow an easy determination of the extinguishing voltage corresponding to a certain arc tube operating voltage under given parameters.

As it is desirable to design self-ballasted lamps also, for reliable operation on 50-cycle power supplies, the curves of Fig. 9 have been determined for this lower frequency, which is customary in some countries of this hemisphere and in Europe. The results cannot be reported in detail because of lack of space. It can be stated, however that under all

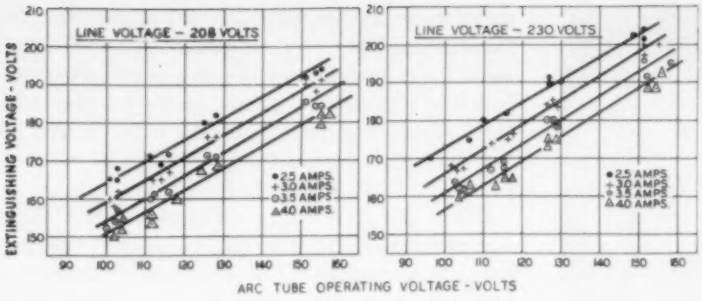

Figure 9. Extinguishing voltage of 400-watt mercury vapor arc tubes of different operating pressures at operating currents between 2.5 and 4.0 amperes, Resistor ballast, supply voltages, 208 and 230 volts, 60 cycles.

operating conditions of practical self-ballasted lamps, the maximum increase of the extinguishing voltage through frequency reduction to 50 cycles amounts to 3 volts only. This small difference can be taken into account without appreciably affecting the performance of given lamp types. After determining the maximum arc tube operating voltage for a given lamp design from Fig. 9, the corresponding arc tube/filament wattage ratio can be read from one of Figs. 3 to 6. In most cases this ratio will be found close to 1.2:1. The corresponding lumen ratio is at least 5:1, and may amount to as much as 10:1, if filaments of very low efficiency are used.

Overloading of the filament during the warm-up period of the arc tube. During the warm-up period of the arc tube, the filament is overloaded considerably. The influence of this overload on the filament life must be estimated carefully and taken into account for the filament design.

Fig. 10 illustrates the method used for estimating the influence of the overload ratio. The arc tube warm-up current, which passes through the ballast filament is plotted as a function of time. The curve shown represents average values from a number of lamps. The warm-up current begins at 140 per cent of operating current when the lamp is switched on and drops to the normal value after 120 seconds.

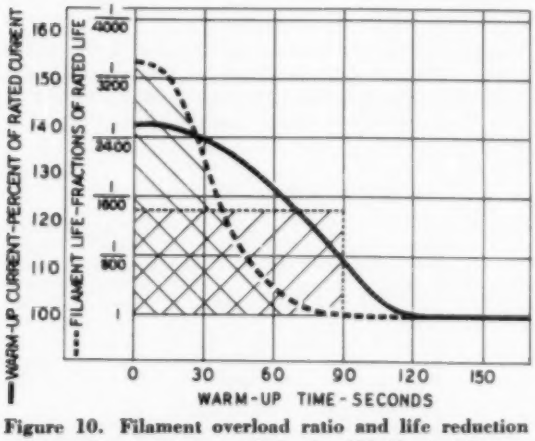

Figure 10. Filament overload ratio and life reduction ratio during warm-up period of self-ballasting lamps.

Every value of the filament overload ratio I/I_o corresponds with a certain life reduction ratio L/L_o according to

$$L/L_o = (I/I_o)^{-24.1} \qquad (3)$$

These resulting life reduction factors are shown in Fig. 10 as a dotted line. They begin with 3400 at the moment of lamp ignition and drop to a negligible value during 90 seconds. It is realized that Equation (3)[11,12] gives inaccurate results when used for such high current variations as is done here. Nevertheless, it supplies the only available quantitative approach to the problem under discussion and the experience with practical lamps has shown that the resulting figures supply a sufficiently accurate approximation.

By replacing the space under the life reduction curve in Fig. 10 by a rectangular area, an average life reduction ratio of 1400 is found. During every lamp start, therefore, the filament operates for a period of 90 seconds at a 1400 times shorter life rate than normal. This means that, in the average, every lamp start reduces the remaining life of the filament as much as 35 burning hours under normal operating data.

The following example will illustrate this further. The filament for a self-ballasted lamp with a rated life of 10,000 hours at 5 hours per start (2000 starts) has to be designed for $10{,}000 + (2{,}000 \times 35) = 80{,}000$ hours. Because of the exponential relation between filament life and efficiency such increase in rated life by the factor 8 results only in an efficiency reduction of about 25 per cent.

This decrease in filament efficiency is only of minor influence upon the total lamp lumens of the type of self-ballasted lamps, discussed here, that operate at a minimum lumen ratio of 5:1. This means that the filament does not contribute more than $^1/_6$ of the total lumen output. A filament efficiency reduction by 25 per cent results only in a 4.2 per cent decrease of total efficiency.

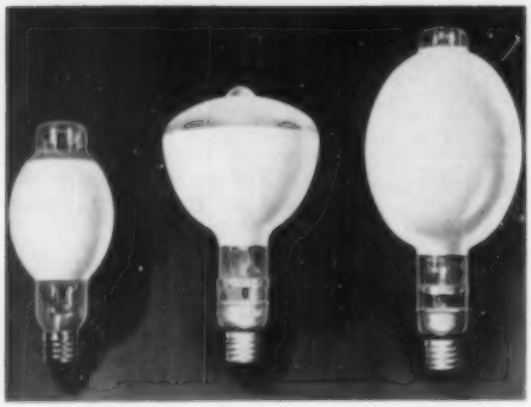

Figure 11. 450-watt, 750-watt and 1750-watt self-ballasted fluorescent-incandescent-mercury vapor lamps in BT-37, R-57 and BT-56 bulbs.

Practical Lamp Types

Three practical types of self-ballasted lamps have been developed so far according to the above described principles and basic data. A 750-watt lamp in an R-57 bulb has been commercially available for some time and has met with considerable success in practical use. Two new types of 450-watt (BT-37 bulb) and 1750-watt (BT-56 bulb) have been designed recently and larger numbers of experimental lamps have been made. Fig. 11 shows the outward appearance of the three lamps and Table II gives their main characteristics. The two new types are developed for 208 and 230-volt power supplies only, while the 750-watt lamp is also available in a special design for 120 volts. All three types are equipped with hard glass bulbs in order to withstand thermal shock and chemical attack over the long rated life.

The inner structure of the new types and the assembly of their components is illustrated by Fig. 12. The filament is mounted on its supports and connected to its leads in a separate procedure similar to the customary practice in the manufacture of incandescent lamps. The mercury vapor arc tube is also mounted and connected separately in its support frame together with the starting resistor. The filament assembly is then joined to the arc tube assembly and both, together, are connected to the stem and sealed into the bulb. In the finished lamp, the filament is arranged symmetrically around the center of the arc tube thus providing an optimum blending of the light from both sources.

Information on lumen maintenance and useful life is contained in Fig. 13. It gives the average lumen maintenance of a considerable number of 750-watt lamps, some of which have been in practical use or in laboratory life test for more than two years. It may be assumed that the 450-watt and 1750-watt lamps will have similar maintenance because they have been designed and rated according to the same principles as the 750-watt lamps. The filaments are dimensioned for relatively low operating temperature in order to outlast the long useful life of the mercury arc tubes on the basis of 5 operating hours per start even under the unfavorable overload conditions during warm-up periods.

Fig. 14 shows the changes in lamp wattage,

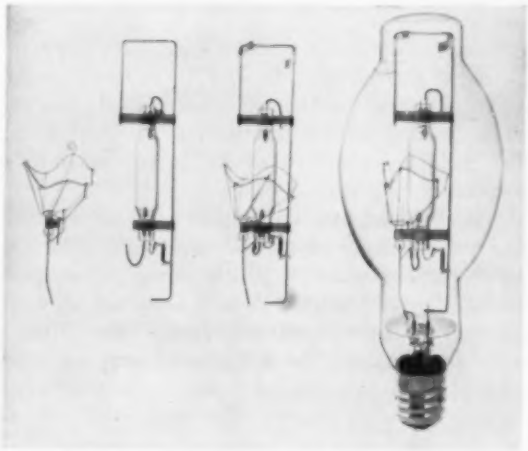

Figure 12. Inner structure of 450-watt self-ballasted lamp. From left to right: Filament assembly, mercury vapor arc tube assembly, filament assembly joined to arc tube assembly, complete lamp.

TABLE II — Data of Self-Ballasted Lamps with Phosphor.

Wattage	Nominal Supply Voltage	Operating Current amps.	Starting Current amps.	Average Initial Lumens	Average Lumens/ Watt	Approx. Red Proportion %	Outer Bulb	Base	Max. Over-all Length Inches	Light Center Length Inches
450	208	2.35	3.3	13000	29	13	BT37	Mogul Scr.	11½	7
450	230	2.15	3.0	13000	29	13	BT37	Mogul Scr.	11½	7
750	208	3.7	5.2	22500	30	11	R57	Mogul Scr.	12½	8½
750	230	3.4	4.7	22500	30	11	R57	Mogul Scr.	12½	8½
1750	208	8.7	12.2	59000	33.5	13	BT56	Mogul Scr.	15 31/32	9 3/8
1750	230	7.8	11.0	59000	33.5	13	BT56	Mogul Scr.	15 31/32	9 3/8

NOTE: When switched on, the lamps have approximately 15 per cent higher than normal lumen output for a period of ½ minute (see Fig. 14). If extinguished, they require four to five minutes cooling time before they will restrike.

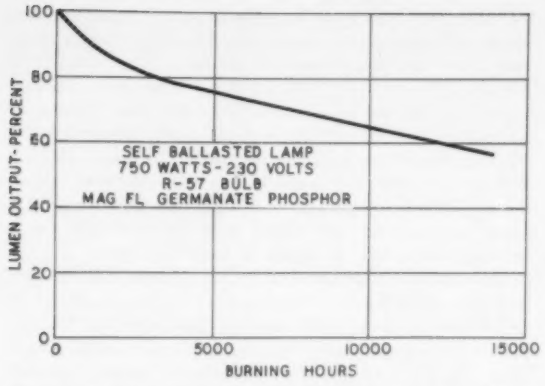

Figure 13. Average lumen maintenance of self-ballasted lamp, 750-watt, 230-volt, R-57 bulb, magnesium-fluorogermanate phosphor.

lumen output and color during the warm-up period. This is relatively short compared to mercury vapor lamps with external ballast because the filament supplies a considerable amount of heating energy to the mercury burner. As the filament operates at an average overload ratio of 1.35:1 during the warm-up period, its lumen output more than outbalances the initial lack of arc tube radiation. The lamps, therefore, have more than 15 per cent higher lumen output during the warm-up time than during normal operation. During this period, the color of the light is of course characterized by an extremely high red proportion and a lack of blue and green (see Fig. 14).

Fluorescent-mercury-incandescent self-ballasted lamps like the above described 750-watt types have been on the market since 1956 under the trade designation "Fluomeric." They have found acceptance in considerable numbers and are successfully used in many installations of diversified character. The 450- and 1750-watt types will be made available within the near future.

The authors gratefully acknowledge the valuable encouragement and assistance given to them by management and engineering staff of Duro-Test Corp. They especially appreciate the help of Messrs. Thorington, Anderson, Swanson, and Cox through numerous discussions; of Mr. Macksoud, who contributed the first designs of self-ballasted lamps,[13] and of Messrs. Creeden, Gruenwald, Dwyer and Spina who assisted in making experimental lamps.

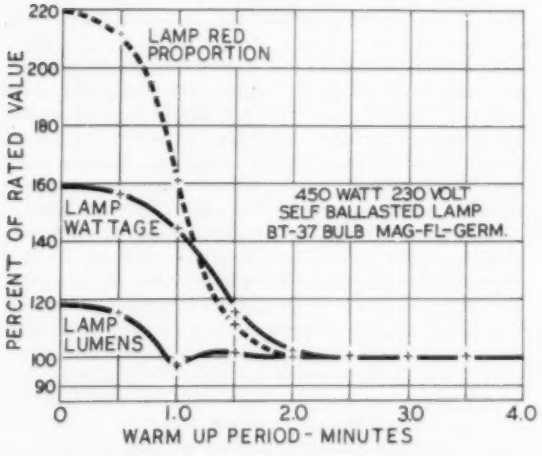

Figure 14. Wattage, total lumen output and red proportion during warm-up period, self ballasted lamp, 450-watt, BT-37 bulb, magnesium-fluorogermanate phosphor.

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DISCUSSION

R. N. THAYER:* This paper is a thorough and commendable coverage of the design parameters of self-ballasted mercury lamps.

Since many of the graphs show design variables as a function of arc tube-filament wattage ratio, can the authors tell us the value of this ratio for the final designs listed in Table II? For example, is the 750-watt design essentially a 400-watt arc tube plus a 350-watt filament? Also, what is the operating efficiency of the filament; is it around the 5-lpw figure listed as one value in Table I?

We have commonly found that discharge lamps ballasted resistively give 5 to 10 per cent lower lamp power-factor than those ballasted by the usual reactive circuits. Have the authors observed this? The designed lamp watts and lumens may then be restored by a corresponding current increase, but the higher rms and peak currents affect lumen maintenance adversely. We would expect lower lumen maintenance figures than those shown in Fig. 13 from this cause, and also from two others: higher arc-tube tempera-

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ture because of the adjacent filament, and blackening in the outer bulb from the filament.

An area of interest to users, not covered by the paper, is the economics of self-ballasted vapor lamps in comparison with conventionally ballasted vapor lamps. Our approximate calculations show a 20-30 per cent greater over-all cost-of-light for the self-ballasted lamps than for conventionally ballasted lamps. Stated another way, the wattage savings of lamp operation on conventional ballasts will pay for their added cost in two years, for typical industrial use. So, the applications of self-ballasted lamps may be chiefly in areas where their higher per cent red and their installation convenience justify the higher cost.

W. S. TILL:* The information in this paper should be very useful to those desiring to design resistance self-ballasted mercury vapor lamps.

In regard to the per cent red light of various sources, I note that Table I of the paper lists 8.7 per cent red for the J-H1 (H1-LB/C). This lamp and other regular improved-color mercury lamps have been improved so that today they average more than 10 per cent red light. Measurements were made with the same type of filter as described by the authors. Along with color improvement, there has also been improvement in the total lumens produced by regular improved-color mercury lamps, through refinements in the phosphor.

The paper did not mention the new deluxe white fluorescent-mercury lamps which I described at last year's conference. The deluxe lamps have from 12 to 15 per cent red, with marked reduction of yellow-green light, giving them excellent over-all color rendition. It is my impression, from direct comparison with self-ballasted lamps, that the deluxe mercury lamps have a distinctly more pleasant color, as well as higher efficiency. I would be interested in knowing if the authors have considered making any self-ballasted lamps using bulbs having the same purple lustre coating as the deluxe mercury lamps, and if so what efficiency might be obtained.

There may be some question about the performance of a 1750-watt self-ballasted lamp in a fixture. Care will have to be taken to see that the bulb does not heat up excessively, and so special fixtures may be required. The temperature dependence of magnesium fluorogermanate phosphor is excellent but its output falls off sharply above 340C, and the per cent red light may be seriously decreased. We would be interested in the authors' comments on this point, inasmuch as it appears to us that temperatures in excess of 400C are likely to be reached with such a lamp in a typical fixture.

R. R. WYLIE:** The basic design data on the lamp discussed in this paper brings up to date the evaluation of resistance-type ballasts for the control of gaseous discharge lamps. The detailed graphs, showing the percentages of red proportion in the red output of the lamps discussed, are of interest in appraisal of the economic justification of this series of sources. The authors have merely proved that the same lighting effects can be obtained by conventional means. The judicious use of mercury lamps ballasted with conventional equipment combined with extended service incandescent lamps will accomplish the same effect. It is true that the maintenance costs of the incandescent lamps will be higher, for they must be replaced more frequently. But under industrial service conditions, where this type of mercury finds its prime usage, it becomes a bit difficult to justify resistance-type ballasted lamps from either the consumer's or the manufacturer's viewpoint. The presence of an incandescent filament in the lamp jacket serves to introduce at least three more places where the lamp can fail. Failure can occur due to shock or to manufacturing abnormalities. These lamps appear to show abnormal sensitivity to voltage variation. In heavy industry, where the lamps are applicable, voltage control is frequently poor.

From the maintenance data of Fig. 13, under heavy-duty industrial conditions, it would appear the economic life of the lamps is about 6000 lumens. The criterion for this statement is simply multiplication of present initial lumens by a realistic dirt and dust maintenance factor. Conventional mercury lamps consistently exceed their maintenance data so their true economic life is superior.

It will be helpful to our understanding of this paper, if the authors can prove the economic justification of resistance-ballasted lamps.

VERN KEMPF:* The authors are to be congratulated on a fine presentation of the difficulties encountered in the design of a self-ballasted mercury lamp. Although the preprint of this paper states that this lamp is only slightly more efficient than a filament lighting source, no mention of this fact was made during the paper's presentation.

Part of my responsibilities as electrical editor of *Plant Engineering* magazine is to interpret the data presented at these technical conferences. Our readers are particularly interested in industrial applications of these new developments. For this reason we have been studying the new fluorescent-mercury-incandescent lamp since early this year.

This lamp has been sold to one plant engineer in the Midwest as being superior to a conventional mercury lighting system. This plant area of 97,900 square feet uses 449 lamps. Investigation disclosed that a total of 9,653,500 lumens were generated in the area to obtain 50 footcandles. If we assume a maintenance factor of 0.80, the average coefficient-of-utilization comes out to 0.635. In the following analysis we have rounded this off to 0.64. This coefficient has been discussed with Mr. Herbert Anderson of the Duro-Test Corp. in correspondence and he agrees that it is realistic.

Our first indication that the fluorescent-mercury-incandescent system was not as efficient as a mercury system came when we compared the maintained lumens per watt of the two systems. This figure came out to 15.7 for the fluorescent-mercury-incandescent lamp. This is considerably below the 26.6 maintained lumens per watt for a conventional mercury system using an improved color 400-watt lamp.

To determine actual costs of operating the fluorescent-mercury-incandescent system, we have compared it to a conventional mercury system using the H400, RC1, 400-watt improved color lamp. Table I shows this comparison. You will note that the fluorescent-mercury-incandescent lamp consumes 700 watts and has a lumen output of 11,000 maintained. This is compared to the 12,450 lumens maintained by the conventional lamp with a watt input of only 468 including the ballast. Both lamps are rated at 6000 to 12,000 hours life and are dependent on burning hours per start. At the moment, I have no information on the lumen maintenance of the fluorescent-mercury-incandescent lamp,

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TABLE I.

	Fluorescent-Mercury-Incandescent	Mercury (H400RC1)
Watts input (includes ballast)	700	468
Lumen output (maintained)	11,000	12,450
Life of lamps (hours)	6,000 to 12,000	6,000 to 12,000
Kilowatt hours consumed (6000 hours)	4,200	2,808
Power cost (at $0.02/per kw hr)	$84.00	$56.16
Lamp cost net each	$49.50	$14.88
Total cost (for one lamp for 6000 hrs)	$133.50	$71.04
Total cost (449 lamps)	$59,941.50	$31,896.96
Difference (6000 hrs)	$28,044.54	
Difference (12,000 hrs)	$40,544.70	

but it seems that oxidation of the filament in the bulb chamber will reduce the lumen output after long burning periods.

At 700 watts, the fluorescent-mercury-incandescent lamp will consume 4200 kw-hrs for 6000 burning hours. The conventional mercury lamp will only consume 2808 kw-hrs in the same period. This is particularly important in this plant as the average cost per kw-hr is around 2¢. The power cost for the fluorescent-mercury-incandescent lamp will be $84 for the 6000-hour period and $56.16 for the 400-watt mercury lamp.

There is considerable difference in lamp costs with the fluorescent-mercury-incandescent costing $49.50 each and the H400 RC1 costing $14.88 net. We can now add the lamp cost to the power cost to determine operating costs for 6000 hours. This comes to $133.50 for the fluorescent-mercury-incandescent lamp and $71.04 for the H400 RC1.

This installation has a total of 449 lamps installed and total operating costs for the fluorescent-mercury-incandescent lamp are $133.50 times 449 or $59,941.50. On this same basis, the total operating costs for the conventional mercury lamp are only $31,896.96.

The difference in operating costs between the fluorescent-mercury-incandescent and the H400 RC1 systems for 6000 hours is $28,044.54. From 12,000 hours, this difference is $40,544.70. It is obvious from these figures that the fluorescent-mercury-incandescent lamp has extremely high operating costs and it would be difficult to justify its use in any situation where standard mercury or fluorescent systems could be used.

The color rendition of the fluorescent-mercury-incandescent lamp is good, but the improved-color mercury sources are adequate and have higher efficiencies. I am personally acquainted with lighting installations in areas where color is used to identify alloy steel bars and the improved-color mercury lamps have proved satisfactory.

One of the reasons given for the installation of fluorescent-mercury-incandescent lamps in this plant was the improved performance of this lamp on variable line voltage that caused some problems with the conventional mercury lamps previously used. The answer to this problem lies in the use of constant wattage transformers and the cost analysis prepared shows that this does not appreciably increase the installed costs of the conventional systems.

In conclusion, I would like to say that the authors are correct in their statement that the luminous efficiency of the fluorescent-mercury-incandescent lamp is higher than that of filament lamps, but lower than the efficiency of mercury vapor or fluorescent sources, although this was not mentioned in their paper. It is this difference in efficiency that makes the fluorescent-mercury-incandescent lamp difficult to justify in industrial applications. The ease of installation is soon lost on the vast differences in operating costs. My recommendations to this plant engineer were to remove the fluorescent-mercury-incandescent lamps and install a conventional mercury system using constant wattage ballasts. The additional expense of putting in the new system would be recovered in a little over a year due to the differences in operating costs.

H. S. STRAUSS AND W. E. THOURET:* We would like to thank all discussers for their interest and favorable remarks. In answer to Mr. Thayer's questions, we believe we have answered the question concerning the arc tube/filament wattage ratio of the final designs by stating, on the sixth page of the paper, that it is close to 1.2:1. Therefore, Mr. Thayer is correct in assuming that the 750-watt lamp contains approximately a 400-watt arc tube and a 350-watt filament. The operating efficiency of the filament is around six lumens-per-watt in the 750-watt lamp. The more recently designed 450-watt lamp filament operates at approximately seven lumens-per-watt.

We have also observed that inductively ballasted arc tubes have a higher power factor than resistance-ballasted ones. For a 400-watt arc tube, we have found a power factor of 0.92 for inductive ballast, and a power factor of 0.88 for resistance ballast. The over-all power factor of our self-ballasted lamps is 0.96.

We agree that higher operating currents may adversely affect the lumen maintenance of given arc tubes. Our arc tubes, therefore, are equipped with slightly larger electrodes designed for these higher currents. Also, the other two mentioned factors do not seem to affect the maintenance of our lamps to a greater extent than the maintenance curve indicates. The blackening produced by the filament on the outer bulb is relatively low because of the low operating temperature of the filament.

We agree with Mr. Thayer's statements concerning the economics of self-ballasted lamps. They will be further discussed in our answer to Mr. Kempf's discussion.

Mr. Till states that he found a red proportion of more than 10 per cent in J-H1 improved-color mercury vapor lamps compared to only 8.7 per cent which we found using the same filter type. This difference may be due to improvements in the phosphor, but we would like to state that our measurements represent an average of recent lamps from different manufacturers. The mentioned difference may also be explained by the tolerances of different filters of the same type. We reported that we found variations of up to 1.6 per cent red when measuring the same lamps with different individual filters. For this reason, we gave the accurate transmittance curve of the filter used for our measurements.

We did not give any comparative values for deluxe mercury lamps because such lamps were not available at the time the paper was written. Since that time, we have obtained such lamps and have included them in the demonstration with a color comparison device that accompanied the presentation of the paper. We agree with Mr. Till that the deluxe mercury lamps have a red proportion of 12 to 15 per cent which is exactly the same amount of red contained in our 450-watt self-ballasted lamp. Concerning Mr. Till's impression that the deluxe lamp's color is more pleasant, we would like to say that the above mentioned demonstration did not seem to show any evidence of this. It is our impression that the deluxe mercury and self-ballasted fluo-

*Authors.

rescent-mercury-incandescent lamps are at least equal as far as pleasantness of color is concerned.

We have not made any self-ballasted lamps using bulbs with purple-luster coating. We do not see any reason for this because the ballast-filament supplies a sufficient amount of red light.

The 1750-watt lamp has not yet been tested extensively in luminaires. We do not expect an appreciable loss of efficiency or color quality in the lamp because of excessive bulb temperature.

If we understand Mr. Wylie's comments correctly, he is suggesting the use of incandescent lamps in separate sockets or luminaires in addition to conventional mercury vapor lamps where their color quality is insufficient. We believe that such arrangements would be much more expensive than the use of self-ballasted lamps. There would be the maintenance cost of the incandescent lamps which require replacement far more frequently than self-ballasted lamps even though extended service incandescents are used. Besides this, either special luminaires or a greater number of luminaires would be required, thus increasing the installation cost.

We have found that the presence of the incandescent filament in our self-ballasted lamps does not make them subject to early failure. As we have discussed in detail, the filaments are of necessity dimensioned for rather low operating temperature in order to withstand the overload during the warm-up period. Therefore, they are not sensitive to shock or voltage variations.

Mr. Wylie's questions concerning economic justification of self-ballasted lamps will be answered together with Mr. Kempf's comments.

Mr. Kempf discusses the purely economic side of the application of self-ballasted lamps. We could not endeavor to cover application and economic matters in addition to engineering information in the limited space assigned to an IES Conference Paper. Therefore, we welcome this opportunity for some brief remarks concerning the economy of self-ballasted lamps.

The average luminous efficiency attained with the present designs of self-ballasted lamps amounts to approximately 30 lumens-per-watt. This is stated repeatedly in the paper, *e.g.*, on the first page and in Table II. It is rather well-known, and also stated in Table I of the paper, that the most popular types of conventional mercury lamps, the E-H1 and J-H1 lamps, attain approximately 46 lumens-per-watt (average ballast losses included in the wattage consumed). Therefore, the luminous efficiency of the self-ballasted lamps amounts to 65 per cent of the efficiency of conventional mercury lamps. As a most na tural consequence of this fact, the operating costs of self-ballasted lamps, calculated on a pure lumen-per-watt basis, must be found higher by a corresponding amount, as stated by Mr. Kempf.

However, it is well-known that the usefulness and economy of a light source in a wider sense cannot be judged solely on the basis of lumen-per-watt. While the self-ballasted lamps have less lumens-per-watt than conventional mercury lamps, they have two decidedly advantageous features. These are: (1) their high red proportion and their otherwise excellent color rendition and (2) the convenience of installation which, in many cases, allows the modernization of lighting installations without rewiring, without the expense for ballasts and often even without new luminaires.

Improved light quality, with respect to color rendition and general pleasantness, alone justifies the higher operating cost in the eyes of many users and owners of installations. While the light quality of regular or improved-color conventional mercury lamps is found adequate in many cases, as stated by Mr. Kempf, a great number of other cases can be cited where their quality is found insufficient and unpleasant. This situation is vividly illustrated by the fact that it has been found necessary and justifiable to introduce the deluxe fluorescent-mercury lamp described by W. S. Till.[1] These lamps attain approximately the red proportion and general color quality of self-ballasted lamps at the sacrifice of about 25 per cent in luminous efficiency. They have only approximately 12 per cent higher lumen output than self-ballasted lamps of the same wattage, but still require the conventional ballast.

The field of street lighting supplies another well-known illustration of the fact that it is often considered justifiable and desirable to sacrifice economy for the sake of better light quality. An increasing number of new street lighting installations is equipped with fluorescent lamps because of their good light quality and pleasant appearance, in spite of much higher over-all cost as compared to mercury vapor installations.

In addition, the installation convenience of self-ballasted lamps makes them both useful and economical for modernization of incandescent lamp installations which cannot be converted to conventional mercury or fluorescent lamps because capital funds are insufficient to cover the cost of rewiring, ballasts and new luminaires. Self-ballasted lamps are also advantageous where modernization is desirable but ballasts cannot be installed conveniently or ceiling conditions do not allow the use of ballasts at all.

What has been said about the justification of the higher operating cost of self-ballasted lamps applies also to the higher cost of the lamps themselves as compared to conventional mercury lamps.

The cost difference is not as large as Mr. Kempf's table makes it appear by comparing the list price of the self-ballasted lamp to the highly discounted price of $14.88 for the regular mercury lamp. We believe that a fair price comparison should be based on list prices because commercial discounts are subject to too many non-engineering considerations. The list price of the H400RC1 weather resistant lamp is $27.75 (self-ballasted lamps are weather-resistant) against the $14.88 used by Mr. Kempf.

Even with this correction, there remains a cost difference between the lamp types. However, we believe that this present price differential should not be used as a basis for passing a general judgment on the economic possibilities of a new light source. Experience shows that virtually all types of sources were relatively expensive when they first appeared on the market as new products. Greater volume of production, refinement and mechanization of methods and design improvements have invariably contributed to substantial cost reductions. In all probability, the cost and price of the self-ballasted lamp will follow the same course. It is also reasonable to expect that its luminous efficiency will be improved over the presently attained values.

Concerning the particular installation to which Mr. Kempf refers, we would like to state that according to information recently obtained by us, the plant engineer is very satisfied with the installation and is not considering Mr. Kempf's recommendation of removing it in favor of a conventional mercury lamp installation with ballasts.

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AUTO DISPLAY — Part I

Sale of cars, both new and used, is a most highly competitive business, and one where lighting has long been recognized for its vital contributions to the desired goal.

Conditions are different in the cases of new cars, where usually a few sample automobiles are on display for order from the factory, and of used cars, where large numbers of autos, to be driven off the lot by the new owners, are parked in fairly large outdoor areas.

Lighting for display of new cars is discussed here, and a coming issue of IE will cover the lighting requirements of used car lots.

New Car Display

By JAMES F. FINN

Four major objectives in the display of new-model cars in show rooms are:

- Attract attention for at least a block,
- Provide highlights and sparkle for the low silhouettes of cars,
- Emphasize focal displays of de luxe car models,
- Speed customer's buying decision.

Exterior Lighting

The first of these objectives starts with identification signs and exterior lighting. Identification signs can be expensive. To enable them to do the best possible job in competing for attention, they should be planned to outshine neighboring business establishments and be located to have clearance from other signs. It is important to discuss a proposed sign with adjoining businesses, to avoid overlapping.

Floodlighting is dramatic on large surface areas but should be used only on light colored surfaces of not less than 25 per cent reflectance and preferably 50 to 75 per cent. Incandescent angle sign reflectors offer a simple way to floodlight an exterior (Fig. 1). If allowed by local ordinances, they should extend out five feet from the building front on swivel arms, which will permit reflectors to retract to the building for lamp changing. Conduit should also be angled above the sign to avoid light scallops which might obscure sign letters. Spacing of five feet between fixtures is recommended. Angle sign reflectors may be painted to match the background of the sign. For greater rigidity, ¾-inch conduit is recommended in preference to ½-inch.

Local authorities should be consulted for approval on the use of this type fixture. In areas where these units are not permitted over the sidewalk, 800 ma or 1500 ma fluorescent lamps may be used in continuous rows. These lamps will operate at temperatures down to −25 F and should be used with outdoor ballasts. Incandescent fixtures, with

TABLE I — Light Sources for Building Front Floodlighting.

Dealership Location	Incandescent Angle Sign Reflectors	Improved-Color Mercury	Low Temperature Fluorescent
Highly competitive.....	500-1000w	400w (H1GL)	200w
Medium competitive....	200-500w	400w (H1GL)	100w
Less competitive.....	150-200w	——	——

Based on a paper presented at the Great Lakes Regional Conference of IES, June 23-24, 1958, Rochester, N. Y. AUTHOR: The Detroit Edison Co., Detroit, Mich.

Figure 1. Incandescent angle iron reflectors offer a simple way to floodlight the exterior of a showroom. Illuminated identification signs also catch the eye.

Figure 2. Illuminated plastic sign in metal frame carries identification message in opaque silhouette lettering.

Figure 3. With lights on, reflections in the plate glass windows are minimized.

Figure 4. Without lighting, reflection of the building across the street adds to the dark appearance.

Figure 5. Highlighting on areas to which the most attention should be concentrated.

Figure 6. General lighting of room. Ratio of highlighting to general lighting should be 10 to 1.

180-degree distribution, extending only 16 inches from the building may also be used. These fixtures should be spaced no further apart than five feet.

Table I gives recommendations for types of lamps for highly competitive, medium and less competitive areas, using incandescent, improved-color mercury and fluorescent sources.

Another effective method of attracting attention is with an illuminated plastic sign (Fig. 2). This sign can be mounted in a plastic-faced aluminum or stainless steel frame over the windows with opaque silhouette lettering illuminated from within by fluorescent lamps. Lamp spacing should be approximately six inches on centers.

Interior Lighting

In considering the show windows themselves, the most common and widely recognized problem is that of reflected images in the windows during the daytime. This, as usual, can be minimized by adequate lighting in the windows and the show room (Figs. 3 and 4). Lighting units should be mounted as close to the front of the window as possible.

Car displays should be placed at least five feet back from the window to assure maximum utilization of the highlighting. The general lighting requirements should be the basis for determining window requirements. A contrast of at least 6 to 1, and preferably 10 to 1, should be provided between highlighting and general lighting. In general, window lighting fixtures should be placed on two-foot centers, and in some instances closer spacing is preferred.

Examples of illumination results using several different sources for highlighting, and assuming 100 footcandles general lighting and window units mounted 10 feet from the grille of the car display, show: 150-watt R40 spot produces 72 footcandles at the center of the spot and a diameter of 7 feet; 300-watt PAR56 narrow beam lamp produces 810 footcandles at center of the spot with a diameter of about 3 feet; 500-watt PAR64 narrow beam spot supplies 1100 footcandles with beam diameter of 2 by 3½ feet.

The PAR56 and 64 narrow and medium beam spotlights are particularly suitable because of the low contour silhouette of today's automobiles, concentrating over 1000 footcandles directly on the area of the automobile for which the most attention is desired. Fig. 5 shows highlighting only and Fig. 6 shows both highlighting and general lighting. Fig. 7 shows aiming of spots and floods on the auto-

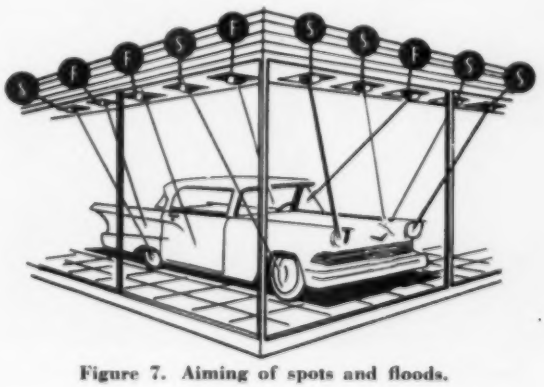

Figure 7. Aiming of spots and floods.

Figure 8. Luminous plastic wall is a fitting background for a featured car. It can be portable or permanent.

mobile: one spot to each headlamp; two spots to center of the grille; two floods to the windshield; and two spots, one each on a front and rear hubcap; two floods, one each, for front and rear panels. Highlighting on the grille is approximately 1000 footcandles, meeting the 10 to 1 ratio previously recommended.

Proper aiming is important. For best effect lamps should be kept aimed at the points they are intended to highlight, and if cars are moved the lamps should be re-aimed. This can easily be done by lining up the center of the beam, using a cord extended from the lamp to the point being highlighted. It is important to avoid aiming lamps toward show room window glass, as this can cause distracting glare.

It is usually desirable to place the lightest car displayed in the focal position along the perimeter of the show window, with darker cars located to the

Figure 9. Light colored car is placed in focal position.

TABLE II — Levels of General Lighting and Lamp Types for Highlighting and Contrast.

Dealership Location	General Lighting Footcandles	Lamp Types for Highlighting
Highly competitive.....	100	300w PAR56 and 500w PAR64
Medium competitive....	75	
Less competitive.....	50	150-200w R40

rear. It is also important that cars do not crowd the area, but rather are positioned with sufficient space for traffic. Recommended spacing is: a minimum of five feet at front, four feet at the rear and six feet on each side of a perimeter car. Car doors of the feature display may be left open for added eye appeal. De luxe cool white slimline 22-watt circline lamps can be mounted at the center of the dome to highlight the car interior. It is also important that recessed floor outlets be provided in the show room area for plugging in special display and interior car lighting.

Another, and completely different, type of display room lighting is a luminous plastic wall (Fig. 8), either portable or permanent, to provide a background for a featured car. It can be mounted in 4-, 6- or 8-foot sections, 6 to 8 feet high, with an opaque back and translucent sides, silhouetted with letter messages as desired. White vinyl or acrylic plastic can be used as the transmitting media. Fluorescent lamps may be installed on 6-inch or 12-inch centers, depending upon the brightness desired for the wall.

Turntables can be used in creating special treatment. These can be dramatically lighted with overhead spotlighting. Mannequins dressed to harmonize with color schemes may be used to advantage. Light neutral pastel colors should be used for walls, with reflectances in the order of 30 to 35 per cent. White ceilings should have reflectance of at least 85 per cent, floors should be 30 to 35 per cent RF.

General lighting can be from recessed, surface-mounted or pendant-suspended fixtures, or luminous or louverall ceilings. De luxe cool white fluorescent lamps are recomended for interior lighting for best all-round color rendition.

Since recessed lighting requires closer spacing of luminaires to reduce brightness contrast, recommendations are for 4 feet on centers, with 6 feet on centers as an outside limit. Average luminaire brightness should not exceed 750 footlamberts.

For ceiling-mounted luminaires, spacing should not exceed 6 feet on centers. On combustible low-density composition ceilings, luminaires should be approved for this type installation, or they should

be mounted not less than 1½ inches from the surface. This is a National Electrical Code ruling under Article 410, Section 4184.

Pendant-suspended luminaires of the direct-indirect type tend to minimize contrast with adjacent ceiling areas, thus providing a pleasant environment. In addition, being self-ventilating, they reduce dust collection. Luminaire spacing should not be more than 8 feet on centers.

Luminous ceilings have the advantage of producing uniform diffuse illumination, and acoustical wedges integrated into the shielding reduce noise and break up the expanse of ceiling.

Louverall ceilings are also efficient, with louvers beneath rows of lamps. However, they may cause distracting image reflections of louvers on the displayed automobiles.

Figure 10. Service area using industrial-type fixtures.

Service Areas

Sometimes service areas are used for sales purposes in demonstrating automobiles. Industrial-type fixtures with 25 per cent upward component are useful in such areas, with equipment centered between bays to assure mechanics the maximum amount of light where needed. Fixtures spaced on 10-foot centers will accomplish this on standard 10-foot stalls. Two-lamp 75-watt 425 ma slimline lamps in 8-foot fixtures are recommended. In addition a continuous row of fixtures should be suspended from the ceiling three to four feet from the wall next to work benches to provide adequate light there and encourage good housekeeping. Hoist lamps as supplementary lighting are available for mounting beneath hoists for under-car lighting.

Display Room of the Future

Design of new cars will probably always be more extreme than that of the show rooms in which they are sold. But a display room of the future (Fig. 11) has several features to give glamor-treatment to cars. Background wall of the display area is of luminous plastic, with colored lamps in changing hues. General lighting is by a luminous ceiling with spotlights for highlighting only the lower perimeter of the car. Car interiors are lighted from within. The de luxe model is displayed on a turntable, adding the attraction of motion. The large transparent sphere contains an actual car, spotlighted from under the cap. Sloping windows minimize distracting reflections from the exterior.

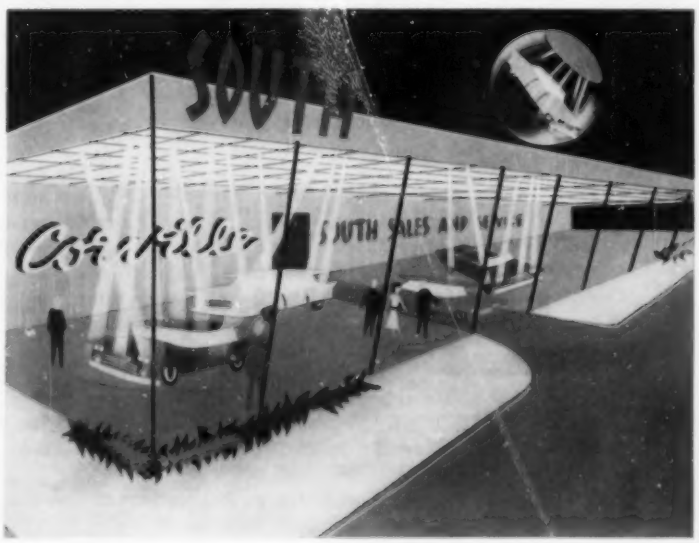

Figure 11. Engineer's visualization of the showroom of the future, with luminous ceiling, highlighting, sloping windows — and drive-in feature.

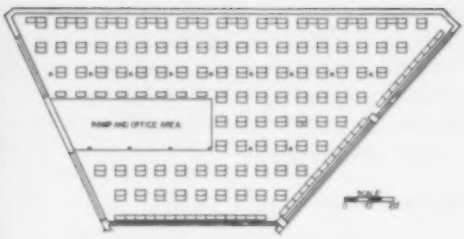

Figure 2. Plan view.

INSTALLATION AT HAROLD B. ROBINSON, INC., 6204 LANCASTER AVE., PHILADELPHIA, PA.

Lighting an Automobile Showroom

LIGHTING OBJECTIVE: To provide comfortable, high level general illumination for the merchandising of new automobiles.

GENERAL INFORMATION: This showroom is trapezoidal-shaped in plan as shown in Fig. 2. The total floor space for merchandising is approximately 9500 square feet. The ceiling height is 9 feet 6 inches. Colors and reflectances of the major surfaces are:

ceiling	white acoustical Fiberglas	80% RF	columns	multi-colored	5-55% RF
walls	mahogany	38% RF	floor	pink terrazzo	23% RF

INSTALLATION: Two hundred and fifty Day-Brite Lighting, Inc. catalog No. 4M490 2-foot by 4-foot troffer units with formed plastic diffusers are located as shown in Fig. 2. Each unit is equipped with four 40-watt T-12 cool white rapid start lamps.

After 1000 hours operation the average level of illumination was 105 footcandles. The brightnesses at that time were as follows:

		luminaire	
ceiling	16 fL	45° crosswise	1300 fL
walls	19 fL	45° lengthwise	1300 fL
columns	3-28 fL	30° crosswise	1215 fL
floor	19 fL	30° lengthwise	1130 fL

Lighting designed by John Logan, Hopkin Bros., and G. Earle Watt, Philadelphia Electric Co.; Electrical contractor, Robert Smith, Jr., 4240 Magee Ave., all of Philadelphia, Pa.

Lighting data submitted by G. Earle Watt and George T. Anderson, Jr., Philadelphia Electric Co., Philadelphia, Pa., as an illustration of good lighting practice and to aid in the design of similar installations.

Published by the Committee on Publications of the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

Series XXIII
2-59

A.I.A. File No. 31

A Versatile Method of Calculating

Illumination and Brightness

By B. F. JONES
J. R. JONES

OUR SYSTEM OF computing interior illumination is based on three fundamental concepts, the maintenance factor, the room index (or room ratio), and the coefficient of utilization. If the correct value for each of these three variables is used in the calculations, the predicted illumination will match the measured quantity. Probably the largest errors in the predicted illumination are caused by misjudging the maintenance factor. Adequate information is not available for use in evaluating this quantity and a comprehensive study coupled with extensive experimental work is needed. While experimental checks are necessary in studying the other two concepts, the basic work is of a mathematical nature. These two subjects will be discussed in detail.

Room Ratio

Our current room ratio system was established by Harrison and Anderson[1] in the period from 1916 to 1920 and was later improved through the efforts of Crouch and Freyer[2] who assembled data provided by Hisano.[3] These data were unavailable in 1920 and later were given insufficient attention. The early work of Harrison and Anderson treated room shape as a ratio that could be computed from a formula. The ratio, regrettably, was abandoned later in favor of the room index in which all rooms of approximately the same shape were called equal through classification by a room index letter.

Our current room ratio system might be called a "double ratio" system. One room ratio formula is used for direct luminaires, another for luminaires that are predominately indirect. For luminaires that direct more than 40 per cent of their flux below the horizontal the room ratio formula is:

$$\text{Room Ratio} = \frac{\text{width} \times \text{length}}{(\text{width} + \text{length}) \times \text{mounting height above work plane}}$$

A paper presented at the National Technical Conference of the Illuminating Engineering Society, August 17-22, 1958, Toronto, Ont. AUTHORS: Smoot-Holman Co., Inglewood, Calif., and Westinghouse Electric Corp., Los Angeles, Calif. This paper accepted by the Papers Committee of I.E.S. as a Transaction of the Illuminating Engineering Society.

For luminaires that direct more than 60 per cent of their flux upward, the room ratio formula is:

$$\text{Room Ratio} = \frac{3 \times \text{width} \times \text{length}}{2 \times (\text{width} + \text{length}) \times \text{ceiling height above work plane}}$$

Setting these formulas equal to each other, it can be seen that the ceiling height above the work plane must equal $^3/_2$ times the luminaire mounting height above the work plane. Therefore, the room ratio can be exact for both the direct and indirect components of suspended luminaires only if the suspension length is one-third the distance from the ceiling to the work plane. Ordinarily, they are mounted nearer the ceiling. Thus, an error is introduced.

Our current tables of coefficients of utilization being based, as they are, on room ratios of 0.6, 0.8, 1.0, 1.25, etc., are not particularly well suited for interpolation in the usual event that one finds a room of ratio of some odd value. An inverse relationship similar to k_r would appear to be better suited to the needs.

Possible Room Classification System

The writers feel that one of the most promising room classification systems would be based on the following principles (see Fig. 1):

1. Divide the room into three basic cavities:
   (a) The cavity above the luminaires,
   (b) The cavity below the work plane,
   (c) The space bounded by the planes of the luminaires on the top, the work plane on the bottom, and the walls of the room.

2. Compute the ratio of the basic room by the formula given in Fig. 1. The cavity ratios for the floor and ceiling cavities can then be found by one slide rule setting, since they are proportional to the heights of the cavities compared to that of the basic room. It may be desirable to use some other symbol than k_r for the ratio of the basic room, to avoid confusion with the present use of the same formula to comprehend the total ceiling height. K_r is being used in this system because it seems to be the best

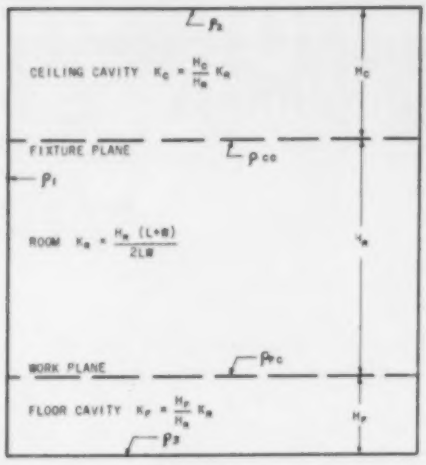

Figure 1. Method of splitting room into three sections. ρ_{cc} = effective reflectance of ceiling cavity; ρ_{fc} = effective reflectance of floor cavity.

currently available system of classifying room shapes, although it represents flux distribution accurately only in a square room.

This treatment of room shape has already been suggested by Caracciolo[4] and others. The principal advantages of this treatment are as follows:

1. It eliminates the "double ratio" system and thus reduces confusion, and adds accuracy.
2. It is well suited to interpolation, thus adds convenience and accuracy.
3. It simplifies the computation of coefficients of utilization. This will be dealt with more thoroughly later.
4. It would permit accuracy in coefficients for rooms in which the walls above the luminaires and below the work plane differ in reflectance from the remainder of the walls (dadoes and so on).
5. It would eliminate the error incurred in instances where the work plane is at some elevation other than 30 inches (or one-fourth the ceiling to floor distance), as is assumed in the systems now current.
6. It yields a method of handling partitions within a room.
7. It focuses attention on the effect of varying mounting height and upper wall reflectance.

The cavity above the luminaires can be treated as a surface at the plane of the luminaires whose reflectance is the effective cavity reflectance. The coefficients of utilization would then be published on the basis of effective cavity reflectance rather than on the basis of ceiling reflectance as is now done. In large rooms having a shallow cavity, the effective cavity reflectance would approach the ceiling reflectance. In small rooms with a deep cavity, the effective cavity reflectance would normally be considerably lower than the ceiling reflectance, particularly if the upper walls were dark. Effective cavity reflectance can be determined from plotted data similar to Fig. 2. This chart and Fig. 3 were computed by a variety of methods all based on the assumption that the flux enters the cavity diffusely. Part was computed by the method used by Spencer[5] and part by the algebraic interflectance method.[6] Caracciolo has also done work on this problem and achieved results which agree with the data in Figs. 2 and 3. In a more comprehensive study of this problem the initial cavity wall bright-

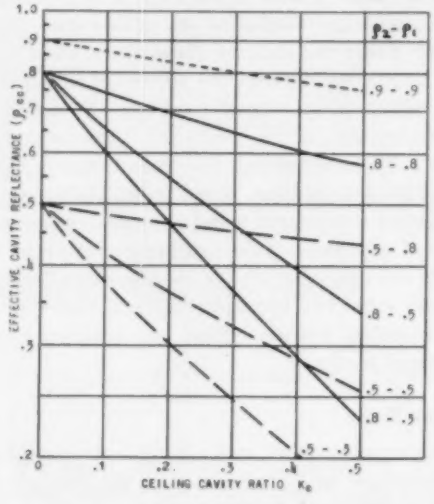

Figure 2. Effective ceiling cavity reflectance as a function of cavity ratio for several combinations of reflectance.

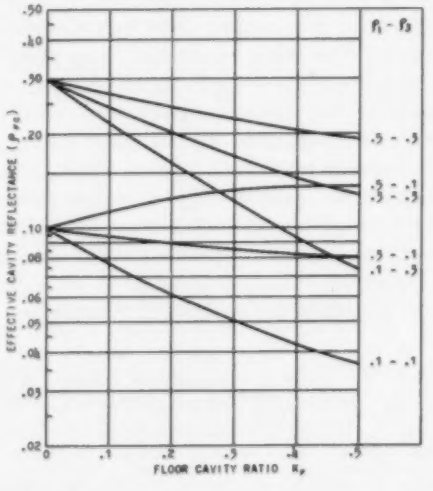

Figure 3. Effective floor cavity reflectance as a function of cavity ratio for several combinations of reflectance.

ness could be varied according to any desired pattern, and studied by means of a computer, and the effect of changing the ceiling ratio studied. Changing the initial brightness pattern affects the effective reflectance somewhat in cavities having relatively high values of K_c or K_f.

Replacing the cavity with a fictitious plane at luminaire height does not impair the accuracy of the coefficients of utilization if the surfaces of the cavity are perfect diffusers and if the brightness of the walls of the cavity is uniform and equal to the ceiling brightness. The currently accepted calculation method makes the same assumptions except that it does not assume the wall and ceiling brightnesses equal. It does, however, assume the flux on the wall of the cavity to be spread out over the entire room wall, inducing an error not present in the proposed system. The assumption of equal brightness for walls and ceiling of cavity is necessary because of the fact that the flux emanating from the cavity is assumed to be diffuse. It is not perfectly diffuse if the walls and ceiling are not equal in brightness. However, the error introduced in the coefficients by a brightness difference appears to be small, of the order of a few per cent in practical cases. It is felt that the benefits stemming from the ability to consider wall reflectances in the cavities that differ from the reflectance of the room walls is ample justification for incurring a possible loss in accuracy caused by a lack of perfect diffusion.

The cavity below the work plane can be replaced by a fictitious plane at the level of the work plane whose reflectance would equal the effective reflectance of the cavity, and otherwise be treated in the same manner as the ceiling cavity.

Thus, the basic room is bounded by surfaces whose reflectances are fairly accurately known. Ordinarily, there is no furniture in this space, and the process of computing coefficients to obtain the illumination on the "floor" of the space is greatly simplified.

Coefficients of Utilization

Our present method of computing coefficients has received more study than that of the room ratio, and has been revised more recently.[7] The present system is based on computing the flux streaming directly from the luminaires to the work plane by the use of zonal multipliers. This has been quite successful, and the zonal multipliers are quite accurate for computing direct flux to the work plane. To the direct flux computed by the zonal multipliers is then added the flux reaching the work plane after reflection about the room. Data provided by Moon and Spencer[8] permitted computation of this flux using interflectance values f_1, f_2, and f_3. Interflectance f_1 is the per cent of flux uniformly incident on the wall surfaces that reaches the work plane. Interflectances f_2 and f_3 are the per cents of ceiling and floor flux, respectively, that reach the work plane.

Several mathematical and experimental studies have been made to ascertain the accuracy of these values. Some studies resulted in reports that indicated a high degree of accuracy; others indicated an error of several per cent under some circumstances. However, it is generally recognized that the published f_2 values are generally accurate except for those for high narrow rooms, especially if the reflectances are low. Other methods are available for computing interflectance values. The algebraic method and a method of Dourgnon[9,10] provide practically identical results. The f_2 values of these two methods are very close to those of Moon and Spencer for all conditions except when the room is high and narrow. However, these values are often *too high* since the final wall brightness is not necessarily uniform as is assumed in the derivation.

Another method for the determination of interflectance values has recently been developed by Professor Philip O'Brien at the University of California, Los Angeles.[11,12] It utilizes a luminous analogue computer that permits determination of the final brightness of the room surfaces to an accuracy of about one per cent, if the room is divided into a large enough number of surfaces. It appears to the writers that a computer to comprehend twelve surfaces is sufficient for most lighting problems. (See Fig. 4.) A twelve-surface computer permits determination of the final average brightness of twelve room surfaces when the initial brightnesses of all twelve surfaces are known. The geometrical disposition of the room surfaces envisioned by the authors is illustrated by Fig. 5, and is based on the assumption the room brightness pattern will exhibit axial symmetry. The assumption of axial symmetry permitted this division of the walls into bands encircling the wall. This necessitated writing the basic flux equations in such form as to permit an exchange of flux between the four sections of the same band. Since it is necessary to know the initial brightness of each room surface (ceiling, work plane and each wall band A, B, C, etc.), a means is necessary for computing or measuring the flux streaming from the luminaires to these surfaces. This suggests the need for additional tables of zonal multipliers or perhaps a new system of photometry that would yield these data directly. For the latter, Losh's[13] approach shows promise.

The initial brightness L_{02} of the fictitious plane

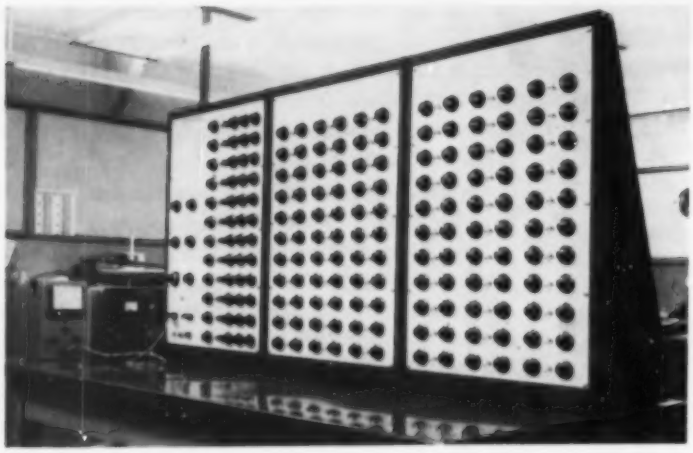

Figure 4. Twelve-surface Luminous Analogue Computer of the type developed by Philip F. O'Brien, UCLA.

at the luminaire level is equal to the product of upward luminaire lumens and effective cavity reflectance, ρ_{ce} divided by A_2, the area of the plane. The effective initial brightness, L_{03} of the work plane, is the product of lumens streaming directly to the work plane (found from the zonal multipliers of Table I) and the effective reflectance, ρ_{fc} of the floor cavity divided by the area of work plane, A_3.

In contrast to dividing the room into many surfaces, as illustrated by Fig. 5, it is possible to consider the walls as a single area of uniform brightness and thus have only three surfaces to consider. This is considered undesirable for two reasons: First, this would not provide a complete knowledge of the brightness pattern of the entire room as is possible if many surfaces are considered. Secondly, it is necessary to divide the wall area into several surfaces in order to minimize errors in the predicted illumination.

In one problem where the walls were considered of uniform brightness, the work plane illumination was 5.1 per cent too high, whereas dividing the walls into ten surfaces yielded an illumination within one-half per cent of the exact solution as computed by Spencer.[14] Since this particular problem had an exact mathematical solution, it was programmed on the computer. The brightnesses of the floor and ceiling, and that of the wall as a function of the distance from the ceiling, were obtained and compared with the exact solution. The wall distributions are compared in Fig. 6, from which it can be seen that the maximum deviation is about 2.5 per cent, and except for the upper two wall sections the deviations are less than one per cent. Table II shows the exact brightness of the floor and ceiling as well as the solution by the Interflectance Method using the approximate kernels[8] and the computer solution. Table III compares the published interflectance values with the computer solution for ceiling brightness and floor brightness as a fraction of the initial ceiling brightness for several common reflectances for a

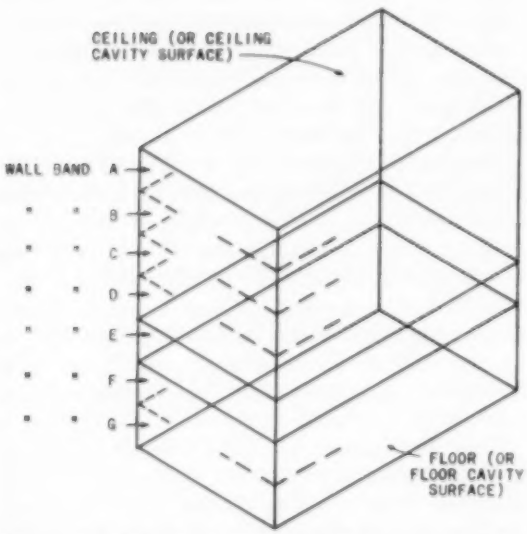

Figure 5. Method of dividing walls into consecutive bands to permit programming of non-uniform brightness distribution on walls. Ceiling cavity surface is plane of luminaires; floor cavity surface is work plane.

TABLE I — Zonal Multipliers.
Room K_r

Zone	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
0-10	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
10-20	.98	.92	.89	.85	.81	.79	.76	.73	.70	.66
20-30	.94	.89	.84	.78	.73	.68	.64	.59	.53	.48
30-40	.91	.82	.72	.64	.56	.50	.43	.36	.30	.25
40-50	.88	.78	.67	.57	.47	.38	.28	.19	.11	.06
50-60	.83	.67	.53	.39	.28	.16	.09	.04	.01	0
60-70	.77	.53	.35	.21	.05	.01	0	0	0	0
70-80	.60	.22	.05	0	0	0	0	0	0	0
80-90	.14	0	0	0	0	0	0	0	0	0

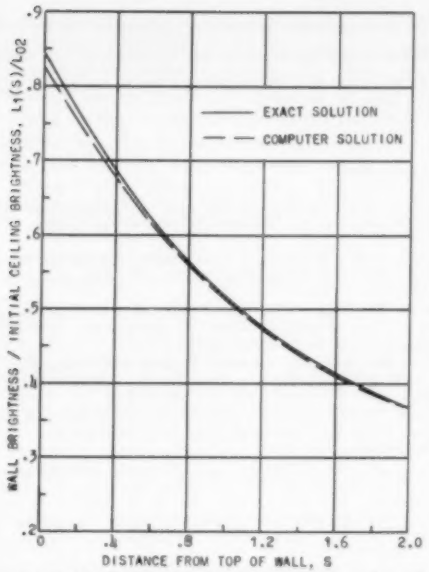

Figure 6. Wall brightness distribution as a function of distance from the top of the wall, referred to initial ceiling brightness. Comparison of exact (mathematical) and computer solutions, using ten wall bands.

cubical room. This procedure could be utilized to provide a set of interflectance tables similar to those presently published, except that the inclusion of tables for each wall band would greatly increase the number of tables required. Therefore, it would be very laborious to use the tables to compute coefficients of utilization. It is felt that a much simpler procedure would be to program the initial brightnesses of the ceiling cavity, floor cavity and wall bands on a computer for solution. This would yield the average brightness of all these surfaces and also provide the utilization factor directly.

Two assumptions are made in this approach which need further verification. Use of the concept of effective reflectance for the floor and ceiling cavities implies that the flux enters and leaves these cavities in a diffuse manner. This is obviously not so in many cases. Examination of the range of ceiling ratios encountered in practice indicates that the error incurred by assuming diffuse flux entry into the cavity would be fairly

TABLE II — Distribution of Light in a Semi-Infinite Room.

	$K_r = 1.0$, $\rho_1 = \rho_2 = .8$, $\rho_3 = .5$				
	Exact	Inter-flectance	Per Cent Error	Computer	Per Cent Error
L_{1F}/L_{02}	.8449	.8276	−2.05	.826	−2.25
L_{1M}/L_{02}	.5166	.5475	+5.98	.515	− .31
L_2/L_{02}	1.4514	1.4751	+1.63	1.446	− .37
L_3/L_{02}	.3499	.3154	−9.87	.3497	− .06

TABLE III — Distribution of Light in a Cubical Room by Interflectance Method and by Computer.

Reflectances	L_3/L_{02}		L_3/L_{02}	
Ceiling/Wall/Floor	Inter-flectance	Computer	Inter-flectance	Computer
80/50/30	1.167	1.158	.087	.1043
50/50/30	1.098	1.096	.0819	.0987
80/50/10	1.154	1.136	.0274	.0333
50/50/10	1.091	1.085	.0262	.0317
50/30/10	1.047	1.048	.0200	.0258

small. To confirm this assumption, the effective cavity reflectance was determined for a luminaire with extreme deviation from diffuse distribution (a concentric ring luminaire) and compared with that for diffuse entry (see Fig. 7). It will be noted that for ordinary combinations of ceiling and wall reflectance, the error is negligible, while for the extreme case of 80 per cent ceiling, 10 per cent walls and a deep cavity ($K_{rc} = .5$) the error is still less than 10 per cent, and in such a direction as to make the calculated reflectance high. Since ceiling reflectance and utilization of flux striking the ceiling are almost directly proportional, this will incur an error in utilization of approximately the same magnitude.

The error due to assumption of diffuse exit of flux from the cavity was investigated by again assuming an extreme case and calculating the error, knowing it will be less for practical cases. The wall brightnesses and floor utilization factor were calculated for a cubical room with totally indirect luminaires of cosine distribution, suspended at one-half the floor to ceiling distance. Exact calculations were made by programming the

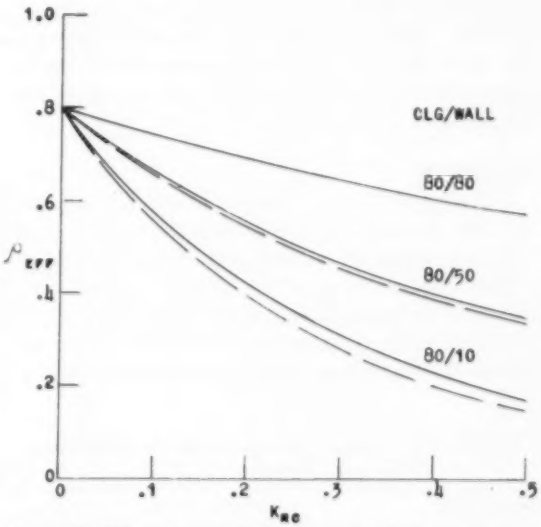

Figure 7. Effect of non-diffuse entry of flux into cavity. Diffuse entry, ceiling ratio = .48 (J Room). Concentric ring luminaire, ceiling ratio = .395 (J).

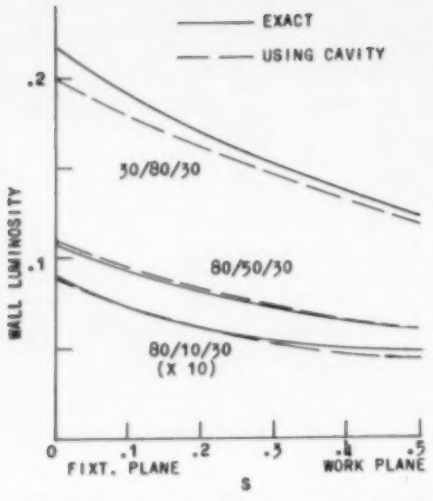

Figure 8. Effect of non-diffuse exit of flux from cavity.

entire room and approximate calculations made by considering the upper part of the room as a cavity whose K_{rc} then equaled .5. Two extreme reflectance combinations and a practical one were chosen. The results appear in Fig. 8 and Table IV. It will be noted that the errors in wall brightness are small, and that only in one of the extreme cases is the error in utilization factor appreciable. This case is for the same wall and ceiling conditions which produced a calculation less than 10 per cent high for non-diffuse entry. Here, it produces an error about 9 per cent low. Therefore, not only are the errors which are incurred by ignoring the non-diffuseness of flux entry and exit from the cavity relatively small, but they are also compensatory. The total error in calculation of surface brightnesses and utilization, therefore, will be quite small for practical cases.

Conclusions

A review of the inadequacies of our present system for making lighting calculations has been made, and a possible system, which overcomes many of the disadvantages of the present system, presented. The major advantage of a system such as this is its ability to comprehend conditions that are outside the limitations of the present system, and to provide a relatively complete picture of the final brightness pattern within an enclosure. A secondary advantage is a substantial gain in accuracy of lighting level calculations.

TABLE IV — Exact and Approximate Utilization Factors.

Reflectances	Utilization Factors		
	Exact	Using Cavity	Per Cent Error
80/10/30	.0839	.0763	−9.06
80/50/30	.205	.202	−1.46
70/80/30	.240	.242	+ .83

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DISCUSSION

D. E. SPENCER:* The method of splitting rooms into three sections, suggested in this paper, is an extension of the procedure suggested in my 1956 paper, "The Effect of Furniture on the Coefficient of Utilization."[1] It has a sound basis in the interflection theory. The effective floor cavity reflectance suggested here is correct if there is no furniture. The values given in Fig. 3 are subject to modification if there are any obstructions in the "floor cavity" as is the case whenever it is worthwhile to introduce such a subdivision. However, suitable value of ρ_{FC} can always be obtained by applying Fig. 3 to each open space between furniture and suitably averaging in the reflectance of desk or table tops. Likewise, the ceiling cavity may contain obstructions which should be taken into account in a detailed calculation.

It is gratifying to see the authors formulate the effect of room shape in a rational fashion in terms of domance k_r.** Their use of the luminous analogue computer appears to be in excellent agreement with the interflection method. The only significant discrepancy shown in Table II could be eliminated if the exact expressions for the direct light on the floor, which I recently suggested,[2] were employed. However, even this discrepancy is less than 10 per cent and therefore I feel that it is of scant practical significance.

*University of Connecticut, Storrs, Conn.

**Domance — index of room proportion.

This process of refining the accuracy with which we can predetermine the brightness distribution in any luminous environment can be carried on indefinitely. However, variations of 10 or 20 per cent in the quantity of light and of 100 per cent in the brightness distribution have so little visual significance that I am inclined to be satisfied with simpler, if less accurate, calculation procedures.

The industry with which the authors pursue increased accuracy is admirable. Their procedures are generally sound. I would merely like to inject a word of caution and a plea that practical procedures for applying the interflection method should not be complicated beyond necessity.

References

1. Spencer, D. E.: "The Effect of Furniture on the Coefficient of Utilization," ILLUMINATING ENGINEERING, Vol. LII, No. 1, p. 35 (January 1957).
2. Spencer, D. E.: "Approximations and the Interflection Method," ILLUMINATING ENGINEERING, Vol. LIII, No. 5, p. 243 (May 1958).

R. T. DORSEY:* These zonal multipliers in Table I are applied to zonal lumens which are derived from average candlepower around each particular zone. In the case of most incandescent downlights, the variation in candlepower around a zone would be relatively small. With fluorescent, luminaires, however, the values vary considerably and so the brightness values calculated for the various wall zones would differ substantially from those which would actually be obtained. In general, with fluorescent luminaires parallel to the wall, the calculated value would be too low, and with the luminaires perpendicular to the wall, the calculated value would be too high.

JEAN DOURGNON:** I found this paper very interesting, primarily because it puts the problem of computations in interior lighting in its true light. For this reason, I am pleased to have the opportunity to comment.

In regard to room ratio, it was not Hisano but Margoulies (in 1928) who first referred to the harmonic mean of the sides of a room, using my own method.

The ratio of height/side of the room for the room ratio has been championed by Phillips in Australia, Cadiergues and myself in France and others. Generally speaking, authors of theoretical works prefer this ratio, while the others prefer the reverse, because they do not want to change the current use, and in a certain way, they are right. Committee W.3.1.1.1 had a resolution in favor of side/height. It could be discussed again, but for my part, I think we must be very careful in this matter.

Regarding possible room classification, at the moment I do not have Caracciolo's paper at hand, but I must say that Caracciolo's idea seems to have been given previously by Zijl. The question is being studied very seriously by Committee W.3.1.1.1.

We have two methods of approach: (1) We assume that the boundary surfaces of the room are at the top, the plane of the luminaires, and at the bottom, the working plane. Both those planes are assumed to have reflection factors equal to the equivalent reflectance of the cavity above or under the plane.

(2) We assume that the room is an ordinary one and has its height "h" between the plane of the luminaires and the working plane equal to the same height "h" of the actual room, but the ceiling and floor are not at their true places, the distances to those planes being constant ratios of h.

Both of these methods are wrong in certain cases. If you want to compute p_{w1}, which I call the partial utilization factor for the walls illuminated alone (from floor to ceiling), you will have a certain amount of flux that flows through the plane of the luminaires. With the first method, you must assume that this flux is uniform on the cavity above the luminaire plane, and calculate the utilization factor and the equivalent reflection factor as if it were. No doubt, this is wrong. It is possible to calculate a rather correct value of the equivalent reflection factor for the direct flux (Fig. A), but the true calculation of the utilization factor is not so easy.

On the other hand, assuming that you have indirect lighting with suspended luminaires, method 1 will be quite correct, but with method 2 you will be obliged to separate the flux on the walls between the ceiling and luminaire plane and assume it is uniform on the whole surface of the walls (between the ceiling and the floor) and use factor p_{w1} which is certainly not the right one for this case.

In regard to coefficients of utilization, the "algebraic" method, O'Brien's method and my method, etc., are but the same method. They have the same assumptions, and the formulas fit these assumptions. The results must be the

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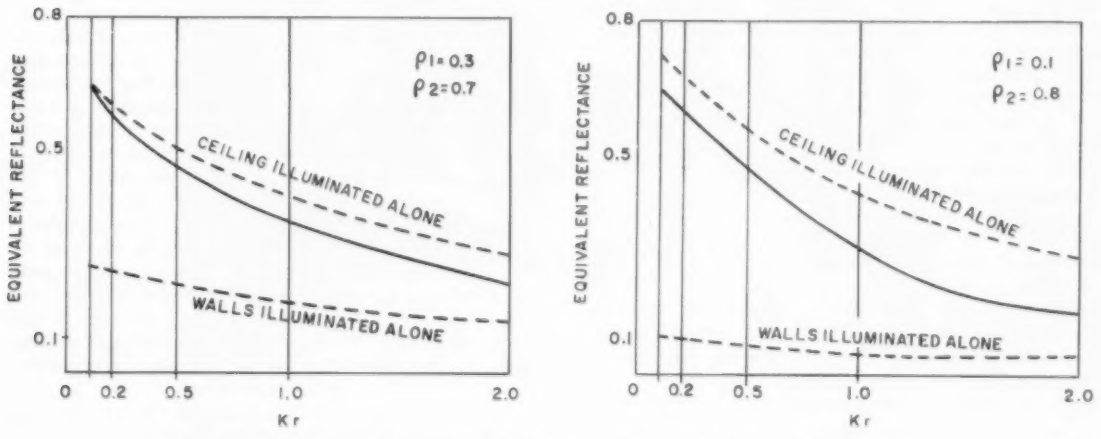

Figure A. Equivalent reflectance of the plane of the luminaires (square room, distance between ceiling and plane of luminaires—0.80 meter)—from Didier Fleury.

same, theoretically, and I am not surprised that they are the same, practically.

In the Bibliography, reference 9 must be wrong. It may be either: Dourgnon, Jean: "Nouvelle methode de predetermination des coefficients d'utilisation," *Revue Generale de l'Electricite*, (Paris), Vol. 23, p. 271 (1928); or Dourgnon, Jean and Cadiergues, R.: "De l'utilisation de l'equation de Fredholm pour la solution des problemes d'eclairage et de chauffage," *Revue Generale de l'Electricite*, (Paris), Vol. 59, p. 299 (1949).

G. W. Clark and M. L. Trostle:* The authors have introduced a rather interesting approach to the further refinement of our coefficient of utilization calculations and to the prediction of the brightnesses of room surfaces. It deserves thorough consideration.

To fully utilize the improvement in coefficients of utilization, it appears that one would have to use the concept of "effective cavity reflectance." We presume this would involve an additional calculation by the user of the coefficient of utilization. This is a deterrent to its use, but not necessarily of sufficient importance to off-set the advantages to be gained. In this respect, it would be similar to the method which we have proposed for predicting the illumination from wall-to-wall translighted ceiling systems where it is so important to adequately consider the influence of the cavity conditions.[1] The data we have published in this manner in our own company literature seem to have been accepted without serious objection.

Fortunately the timing of this paper is such that the extra calculation involved for determining coefficients in the proposed method is not so unreasonable to contemplate as might have been the case a few years ago. Obviously, this is feasible only with the use of computing devices, a trend already underway.

1. Clark, G. W., and Trostle, M. L.: Discussion of Russell, A. H. and Churchill, R. D.: "Measured Utilization Data for Luminous Ceilings," Illuminating Engineering, Vol. LI, No. 4, pp. 316-317 (April 1956).

Philip F. O'Brien:** This excellent paper is concerned with the predetermination of the luminous flux distribution in symmetrical rooms. Twelve finite difference equations which describe an infinitely long hallway are solved using a Luminous Analogue Computer. The evaluation of the coefficients of these finite difference equations requires a knowledge of the shape modulus. Because information regarding the mathematics of the shape modulus and the numerical values of this geometrical parameter is distributed throughout the literature of radiative transfer, lighting engineers may find this lack of unified information a barrier to the utilization of this design tool.

The effective reflectance of certain cavities in a room is suggested as a device to simplify the analytical representation of flux transfer. By this artifice, the complicated network of the cavity is replaced by a single network branch containing the resistance $\rho nc/(1-nc)A$. Although simplicity is gained, the reduction of network branches makes unavailable information regarding the directional aspects of flux flow within the cavity and between the cavity surfaces and the room. For example, the initial flux streaming from the cavity defined by the luminaire plane should be computed from a detailed network representation of the cavity in order to account for the trapping effect which is sensitive to the directional aspects of the flux streaming upward from the luminaires. Dourgnon[1] has recently treated this problem of flux transfer in the ceiling cavity.

Because contributions to this problem of lighting predetermination are being made at an increasing rate on a world-wide basis, the lighting engineer who wishes to be up-to-date in this area must read many papers with a variety of nomenclatures and notations. For example, the effective ceiling cavity reflectance ρ_{cc} of this paper has been designated by other authors as: effective reflectance ρ_{EFF}, *fattore apparente di reflessione* r_a, equivalent reflectance ρ_{eq}, *le facteur de reflexion equivalent* ρ_e and R_o, equivalent reflectance factor of cavity, and apparent reflectance ρ_2*. If the rapid growth of this technical area prevents the early use of standard notation, it may not be unreasonable to expect each author to define quantities by a functional relationship with each term identified by typical units or dimensions.

The authors are to be commended for this first report of the application of the network representation of lighting systems in an industrial environment. I look forward to additional reports of the utilization of the Luminous Analogue Computer both for the design of room lighting and for the analysis and synthesis of luminaires.

1. Dourgnon, Jean: "Recherche Preliminaire sur la Diminution du Facteur D'Utilisation Suite de L'Occultation des Appareils D'Eclairage," *Cahiers du Centre Scientifique et Technique du Batiment*, Paris, June 1958.

B. F. Jones and J. R. Jones:* We would like to express our appreciation to the discussers of this paper for their kind comments. There is really little to rebut, and what there is is due mainly to differences in viewpoint.

Rather than using a difference exact expression to obtain light on the floor for each room shape, as suggested by Dr. Spencer, it might be preferable to calculate tables of interflectances by computer, thus removing those inaccuracies occasioned by the approximations of the equations.

The visual significance of 10 or 20 per cent variations in intensity is not at issue in this discussion. We need, for at least three reasons, to perform calculations as accurately as possible. First, by starting from an accurate base, the unavoidable deviations (in lamps, voltage, etc.) moves us less far from the correct value, on the average. Second, specification of footcandle levels is becoming more general, and with the present competitive situation, it is often necessary to calculate quite accurately. Finally, an accurate calculation method raises the stature of the illuminating engineering profession in the eyes of the other professions.

Mr. Dorsey's comments are basically the same as those voiced in discussion of the original zonal method, which was subsequently adopted as the current IES standard. It should be remembered this is an engineering method of calculation, and must be simple enough for rapid and convenient use by the engineer. An extremely accurate calculation of brightness could be made by dividing the areas involved into a sufficient number of elements and programming them on a computer of sufficient size. We feel that the time required for such calculations is justified in only a very few cases. The average brightness of wall surfaces given by this method is a definite advance over those previously available for engineering use.

We particularly thank Mr. Dourgnon for his comments and for giving us the international view on the problems

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**Department of Engineering, University of California, Los Angeles, Calif.

*Authors.

involved in a unified calculations system. We should very much like to see more work done on the problem of an accurate system of room classification, since no current system adequately represents all room shapes. We do not look with favor on the adoption of the resolution in favor of side/height.

Mr. Dourgnon did not have the benefit of the additional checks on non-diffuse entry and exit of flux from the cavity when he wrote his discussion. Thus, while his comments relative to the first method of approach (which we used) are quite accurate, the magnitudes of error introduced in practice are quite small.

We bow to Mr. Dourgnon's more intimate knowledge of contributions from outside this country. Unfortunately, we in the United States undoubtedly pay too little attention to the work of our colleagues overseas.

The incorrect bibliography reference pointed out by Mr. Dourgnon has been corrected for publication in ILLUMINATING ENGINEERING.

Effective cavity reflectance, referred to by Messrs. Clark and Trostle, can be obtained from charts similar to Figs. 2 and 3, which would be made available for whatever combinations of reflectance were felt desirable. The only additional calculation is of the cavity K_r which is obtained at the same time as room K_r, as noted in the paper.

Regarding Professor O'Brien's comments, the directional aspects of the flux streaming from the cavity do not seem to have great effect on the illumination and brightnesses within the room, as can be seen from Fig. 8. The effect of luminaire trapping, however, needs a good deal of research. Incidentally, such research would be greatly facilitated by the use of the computer. Obviously, it would affect this system only by modifying the value of the effective cavity reflectance.

We feel it would be quite desirable for a standard notation to be developed at this time, and we believe that the I.E.S. Nomenclature Committee, of which Professor O'Brien is a member, is currently working on this.

Polar Palace Relighted

A 48-foot ceiling height at the center of Polar Palace ice skating rink, Los Angeles, made maintenance a real problem with the previous lighting system of suspended units. In relighting the 21,000-square-foot area, the fixtures were installed along the sides of the building just below the supporting tie rods. Continuous rows of 96-inch four-lamp units with acrylic diffusing panels are mounted at an angle of 30 degrees to the vertical, 28 units on each side. Units are wired for switching from two to four lamps for various levels. Colored PAR-38 reflector lamps are installed on alternate columns to create the desired atmosphere for specialty performances. Walls and woodwork were repainted for higher reflectance. Illumination level is from 8 to 10 footcandles. Photo and data courtesy Department of Water and Power, Los Angeles, Calif.

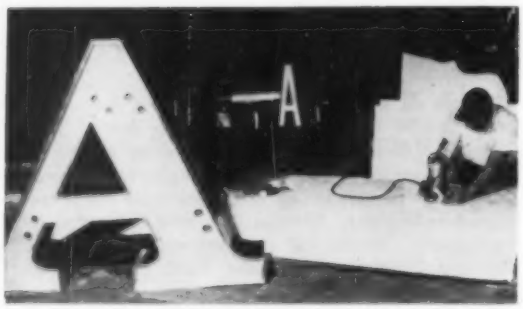
Trotters attract crowds from New York City, who travel the Thruway until they see the

Sign at Yonkers Raceway

RACING enthusiasts who follow the trotters at Yonkers Raceway, New York, are now guided to their destination by an identifying sign visible a mile away. Letters spelling out the name of the track are 4½ feet high.

The fourteen letters were first blocked out in stainless steel frames. The inside reflecting surfaces were painted white and four neon-filled tubes installed in each frame. Acrylic plastic letters matching the frames were machine-cut from twelve ¼-inch thick sheets. Two "E's" and two "A's" were made from a single 67- by 102-inch sheet. The plastic pieces were then fitted into the lip of the steel frame and screwed into place. The completed letters were delivered to the race track where they were hung on the wall with angle irons.

Fabrication and installation by Artkraft-Strauss, with Commercial Plastics & Supply Corp., both of New York City.



Router rough-cuts letter "A."

Plastic letter "O" is slipped into steel frame.

Completed letters are mounted on building.

Multilayer Polarizers

and their application to General Polarized Lighting

By ALVIN M. MARKS

THE OBJECT of this paper is to describe the properties of multilayer polarizers and their unique application to general polarized lighting, as well as the results obtained through the use of general polarized illumination. Particular reference will be made to the improved visibility on the task and a large improvement in perception of the surrounding areas.

The application of multilayer polarizers to general polarized illumination was first disclosed by Marks in a series of patents.[1-4] Many structures have been studied for this application, including thin layers of glass sheets, plastics, multilayered films on glass and sheets composed of layers of flake glass having air interstices between the layers of flakes. The principles discussed herein apply to all forms of multilayer polarizers; however, the results obtained will be specified as to the type of multilayer polarizer employed in connection with the tests.

A clear distinction must be made between the linear type of polarizer commonly employed for sun glasses or camera filters and the like, and the multilayer polarizing materials of this paper. In the illumination field, the multilayer polarizers possess certain inherent advantages over the linear type polarizers, as will be seen from the following discussion.

The linear type polarizer had been used commercially, to a limited extent, in desk lamps, but could not be used successfully in the field of general illumination because of certain inherent disadvantages which will be apparent. Fig. 1a shows a linear polarizer sheet 3 with an ordinary unpolarized ray of light 1, indicated by a star placed on the ray, transmitted partially through the sheet 3 and emerging as polarized ray 2. With the conventional type linear polarizing sheet 3 shown, the ray 2 is polarized and transmitted to the extent of only about 35 to 45 per cent of the initial ray 1.

Fig. 1b shows a multilayer polarizer sheet 4 with unpolarized ray 5 impinging on the sheet 4 and

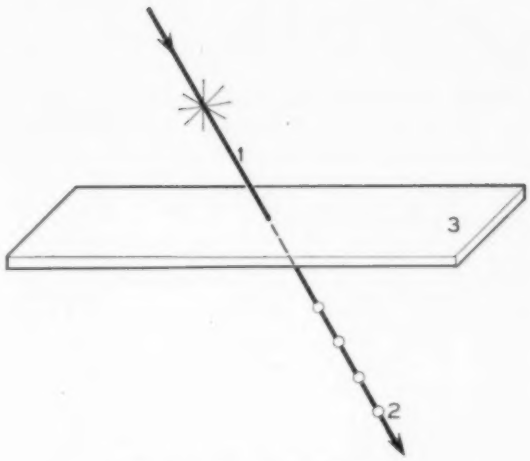


Figure 1a. Linear polarizer.

splitting up into two rays, a reflected ray 6, polarized in the plane of the diagram, and a transmitted ray 7, polarized normal to the plane of the diagram. If the multilayer polarizer contains a sufficient number of layers, and if these layers are thin and transparent, the reflected ray 6 and the transmitted ray 7 will contain approximately equal amounts of energy, but polarized at right angles to

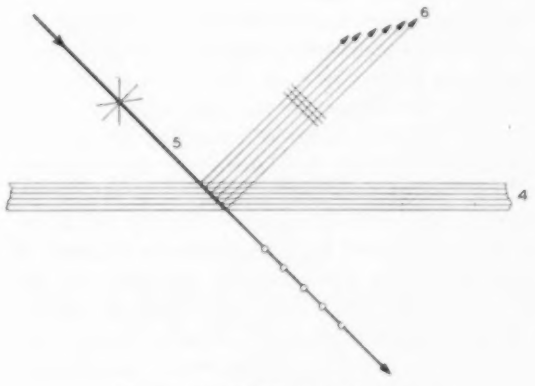


Figure 1b. Multilayer polarizer.

AUTHOR: Polarized Lighting, Inc., Whitestone, N. Y.

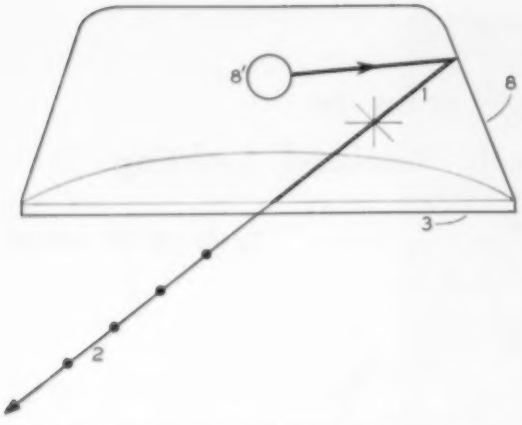


Figure 1c. Linear polarizer and light in reflecting enclosure.

each other, as shown. Substantially, no absorption will occur in the sheet 4.

In their application to general illumination, multilayer polarizers lead to interesting consequences. If the linear polarizing sheet 3 is placed at the bottom of the luminaire 8 in Fig. 1c, only about 35 to 40 per cent of the available light energy from light source 8 will be transmitted through the sheet 3 and polarized as shown in 2. However, if as in Fig. 1d, we place a multilayer sheet 4 at the bottom of an enclosed luminaire 8 which has been coated on the interior surface with a white diffusing reflecting coating, 9, such as a magnesium dioxide or titanium dioxide white paint, then new and unexpected phenomena occur. One of these phenomena, which I have termed "reflux polarization," results in a high quantitative yield of the available light energy as polarized light.

Lighting efficiencies of approximately 70 per cent relative to the unshielded lighting units may be achieved with luminaires equipped with multilayer polarized panels. Thus, multilayer light polarizing panels are comparable in lighting efficiency to the commercial type of diffusing shielding media commonly employed. In addition, they have the advantage of yielding polarized light, that is light vibrating in particular planes and providing increased visual acuity, as will be shown.

The "reflux polarization" action of the multilayer polarizing sheet 4 is shown in Fig. 1d. A ray of ordinary light 5 from any point on a source of light 8′ within the luminaire impinges on the multilayer polarizer 4, and approximately 45 per cent is transmitted as ray 7. Another 45 per cent of the ray 5 is reflected as a vertically polarized ray 6. About 10 per cent of the ray 5 may be absorbed in the multilayer polarizer. Upon striking the diffusing coating 9, the ray is depolarized and reflected as scattered ray 10. Assuming a reflection factor of approximately 85 per cent, 38 per cent of the initial light energy is present in the ray 10. Ray 10, which is ordinary unpolarized light, again strikes the multilayer polarizer 4 and is transmitted as another horizontally polarized ray 7′ containing 17 per cent of the initial energy. Another 17 per cent of the initial energy is also reflected as vertically polarized rays 6′ which strike the depolarizing diffusing coating 9. These are again reflected as ordinary unpolarized scattered rays 10′, which comprise 17 per cent times 85 per cent, or approximately 14 per cent of the available light energy. Rays 10′ are again transmitted, as rays 7″ through the multilayer polarizer 4, to the extent of approximately 45 per cent of 14 per cent or 6.3 per cent. In a similar manner, subsequent reflections, depolarizations and transmissions produce additional percentages of approximately 2 per cent, 0.6 per cent, 0.2 per cent, etc.

Summing all these transmissions (45 + 17 + 6.3 + 2 + 0.6 + 0.2 + . . .) a total of approximately 71 per cent is the resultant, in this example. This process has been named *reflux polarization*.

In the above calculations, an absorption loss of approximately 10 per cent is assumed in the multilayer polarizer, which is approximately true for 16 layers of thin isotropic plastic sheets.

For light rays, such as ray 12, transmitted normal to the plane of the multilayer polarizer 4, or approximately so, no polarization is produced. However, the reflected component 13, of the approximately normal ray 12, will contain a higher proportion of the initial light energy than that

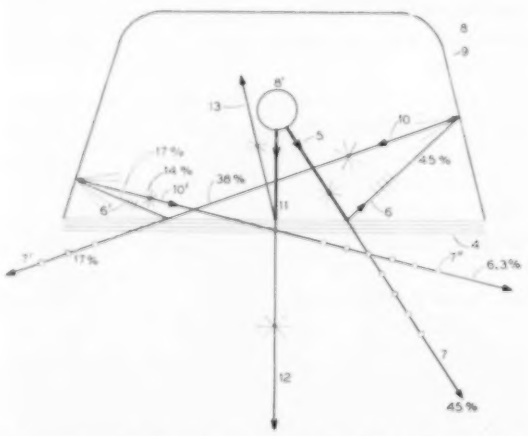


Figure 1d. Multilayer polarizer and light in depolarizing reflecting enclosure, showing reflux action and percentage transmissions. (Note: Angle of incidence *is* equal to angle of reflection. Error is in drawing.)

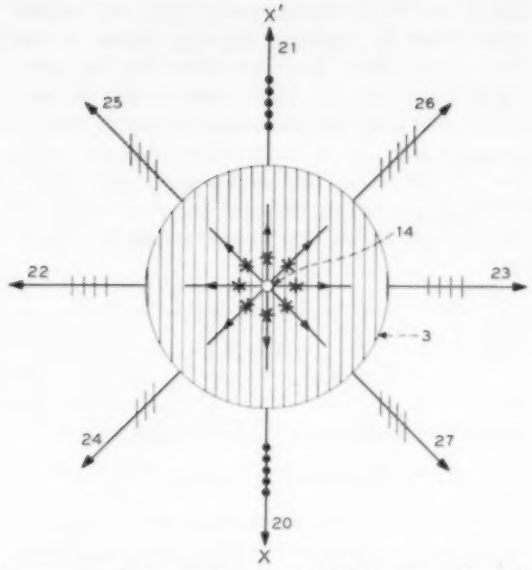


Figure 1e. Linear polarizer with light source above it and conically distributed light passing downward through the linear polarizer showing variation in direction of plane of polarization of the rays, with reference to the planes of incidence.

contained in the reflected component 6. The transmission factor of the approximately normal ray 12 is lower than that of the transmission factor for rays transmitted at angles, such as the rays 7 and 7'. Thus, the transmission of the approximately normal rays is partially suppressed and the transmission of the oblique rays such as 7, 7' and 7" is favored. In other words, the normally transmitted beam which is not polarized is considerably reduced in transmission, and the polarized beam which is spread conically about the normal axis is favored as to transmission. This is substantiated by comparison of the data of Figs. 3b and 3c with those of Figs. 11 and 13.

Fig. 1e shows a conventional linear polarizer in plan view with a light source 14 situated above the polarizer 3, and with the polarizing axis of the sheet 3 along the axis line XX^1. Rays 20 through 27 from the source 14 proceed downward through the sheet 3 and spread out in a diverging cone onto the horizontal floor beneath.

Rays 24, 25, 26 and 27, which are proceeding at an angle between 0 and 90 degrees to the axis XX^1, will be polarized at some other angle to the plane of incidence of these rays, neither in the plane of incidence nor at right angles to the plane of incidence. In Fig. 1e, only those rays 22 and 23, polarized normal to the plane of incidence by being transmitted at right angles to the axis XX^1, and substantially only those rays included between rays 26 and 27, and 24 and 25, covering an angle of approximately ±30 degrees about the rays 22 or 23, are in such plane of polarization, as to be effective for substantial refraction into the object being viewed.

On the other hand, rays 20 and 21 and a sector comprising approximately ±30 degrees to either side of these rays are polarized approximately in the plane of incidence. These rays are substantially reflected from the object being viewed, and thus accentuate the specular glare.

It is apparent from a study of Fig. 1e that the linear type polarizer is unsuitable for general polarized lighting, since it can only be used with specifically directed rays. On the other hand, by referring to Fig. 1f, which shows a plan view of a multilayer polarizer 4, a light source 30 and rays 31 through 38 inclusive, proceeding downwardly from the light source 30 through the multilayer polarizer, it will be apparent that all the aforementioned rays are polarized normal to their respective planes of incidence. All the rays 31 to 38 inclusive, therefore, are in a condition to be preferentially refracted into any viewing surface upon which they may impinge. Thereupon, all rays 31 through 32 proceeding in all radial directions, are effective to reduce specular glare upon surfaces in all directions under the luminaire. Therefore, the multilayer polarizer 4 may be employed with general polarized illumination, that is, all rays from a luminaire proceeding in all directions through a multilayer polarizer, preferentially refract into

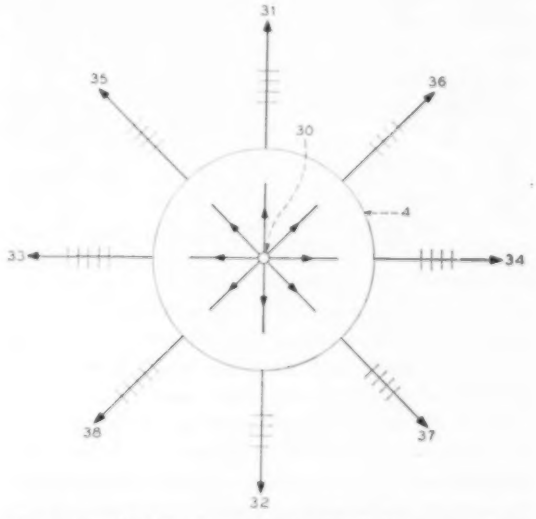


Figure 1f. Multilayer polarizer, with light source above it, and conically distributed light passing downward through the multilayer polarizer, showing the plane of polarization always normal to the radial planes of incidence, this effect being termed "radial polarization."

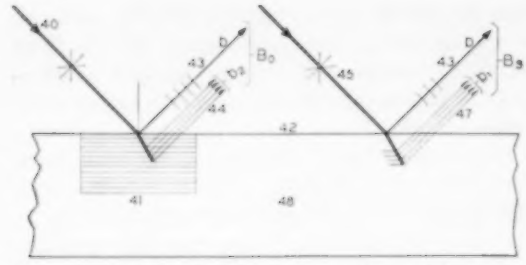


Figure 2a. Reflection components for ordinary unpolarized light from an idealized section of a "dark" area, and an adjacent "light" area, comprising a surface reflected component, and a refracted-reflected component from underneath the surface. (Note: number 43 at extreme right should read 46.)

any visual task which is underneath the luminaire.

The polarizing vectors in Fig. 1f are always normal to the plane of the incidence from whatever ray and in all radial directions of these rays. The phenomenon shown in Fig. 1f has been given the name *radial polarization* to distinguish it from the linear polarizing action shown in Fig. 1e.

How We See

General effects of ordinary unpolarized and polarized illumination on the visual task are shown in Figs. 2a and 2b, respectively. Fig. 2a shows conventional unpolarized rays from a light source (not shown) impinging upon an object *O*, which may comprise a bright surrounding area 48 and a dark area 41, the object being viewed, 48 being termed the surround. The ray 40, being unpolarized, is partially refracted into the pigmented area 41 and is then reflected as a scattered beam 44 of reduced brightness b_2 (containing altered color characteristics if the area 41 be pigmented by a color pigment). The surface of the object 42 reflects uniformly, and shows up as a brightness b, regardless of the position of the ray over the surface, whether it be on the dark pigmented area 41, or over the bright unpigmented area 48. This is because only the refracted beam can be affected by the pigment. The reflected beams 43 or 46 are unaffected by the pigment characteristics of the regions below the surface, and therefore, are of a uniform brightness b over the entire surface, regardless of what pigment there may lie below the surface. Thus, the ray 45 striking the bright surrounding area 48 is reflected from the surface with a brightness b as ray 46, and is also partially refracted below the surface and scattered back as the brightness b_1 as ray 47.

We now refer to Fig. 2b which shows an object identical with that shown in Fig. 2a; however, rays 40 and 45 have been replaced with polarized rays 50 and 51, which have been polarized normal to the plane of incidence, that is, normal to the plane of the paper. They are shown for the condition in which the rays totally refract into the surface 42, and then emerge as rays 44 and 47, having a brightness b_2 and b_1 for the pigmented and white areas, respectively. The brightness of rays 50 and 51 may be altered by constant factor a relative to that of rays 40 and 45, without changing the result.

Contrast C may be defined as follows:[12]

$$C = \left| \frac{B_s - B_o}{B_s} \right| \qquad (1)$$

where B_s = brightness of the surround,

B_o = brightness of the object.

In Fig. 2a, the total brightness of the light reflected from the unpigmented and pigmented areas, respectively, are split into components and shown in the following equations:

$$B_s = b_1 + b \qquad (2)$$

$$B_o = b_2 + b \qquad (3)$$

In Fig. 2a, it will be assumed that the reflected component b is everywhere reduced by an amount b', by partially polarized light incident at any angle other than the normal, that this light b' is instead refracted into the surface, and that the total reflected light from below the surface is then increased to $b_1(1+b')$ and $b_2(1+b')$ respectively, because of the additional amount of light refracted into the surface. It will be particularly noted that this derivation is independent of the angle of incidence and the percentage of polarization.

For the case just discussed, the brightnesses B_s and B_o became B_s' and B_o' as follows:

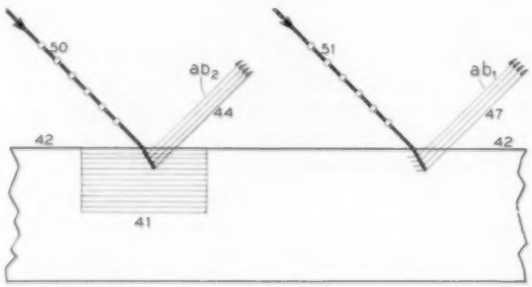


Figure 2b. Refracted-reflected component from underneath the surface only, using light polarized normal to its plane of incidence, from an idealized section of a "dark" area and an adjacent "light" area. The surface-reflected component is entirely absent in this illustration because of the polarized light and angle of incidence.

$$B_s' = b_1(1+b') + (b-b') \tag{4}$$

$$B_o' = b_2(1+b') + (b-b') \tag{5}$$

$$C = \frac{b_1 - b_2}{b_1 + b} \quad \text{(Unpolarized)} \tag{6}$$

$$C_p = \frac{(b_1-b_2)(1+b')}{b_1(1+b') + (b-b')} \quad \text{(Polarized)} \tag{7}$$

$$\frac{\Delta C}{C} = \frac{C_p - C}{C} = \frac{C_p}{C} - 1 \tag{8}$$

$$= \frac{(b_1-b_2)(1+b')}{b_1(1+b') + (b-b')} \cdot \frac{b_1+b}{b_1-b_2} - 1$$

$$= \frac{(1+b')(b_1+b) - b_1(1+b') - (b-b')}{b_1(1+b') + (b-b')}$$

$$= \frac{(1+b')b - b + b'}{b_1(1+b') + (b-b')} = \frac{b + bb' - b + b'}{b_1(1+b') + (b-b')}$$

$$\frac{\Delta C}{C} = \frac{b'(1+b)}{b_1(1+b') + (b-b')} = \frac{b'(1+b)}{B_s'} \tag{9}$$

For the condition shown in Fig. 2b, $b = b'$ at Brewster's angle for incident light which is 100 per cent polarized.

$$\frac{\Delta C}{C} = \frac{b}{b_1} \tag{10}$$

Since b, b' and b_1 are always positive, it follows from equations (9) and (10) that there is always an increase in the contrast when employing partially polarized light at all angles of incidence, compared to the contrast under unpolarized lighting conditions, except at 0 degrees, where the contrasts are the same. There is an increase in contrast however small b' may be. Therefore, polarized light, when radially polarized, may be said to always increase the contrast of the object viewed relative to its surround. We may also see from the formula (10) that this increase in the contrast is particularly marked in the case of low brightness surrounds.

It has been shown by Chapanis[5] and others[6,7,8] that *visual acuity increases with the contrast.* It has been further shown by Cottrell[9] and others that for a given illumination intensity, the threshold for visual perception increases with the inherent contrast of the object being viewed relative to its surround.

The contrast ratio, r is defined by:

$$r = \frac{B_s}{B_o} \tag{11}$$

The contrast ratio as defined in (11) is related to the contrast C defined in formula (1) by the following relation:

$$C = \frac{r-1}{r}$$

The experimental test set-up shown in Fig. 12a shows a means for measuring contrast ratio. The light projector 91 projects a beam of light 92 onto an area 93, on which are alternately placed white and black printed newspaper in large areas. The reflection is measured by the photocell 94, and the meter 95 at an angle θ, where the angles of incidence and reflection are equal. The reading for the reflected light from the white area is divided by the reading for the reflected light from the black area, and the ratio r is computed as in (11) and plotted for ordinary light in Fig. 12b, curve a. The results with the multilayer polarizer 96 are plotted in Fig. 12b, curve b. The multilayer polarizer used in these tests was 18 thin layers of cellulose acetate, .001 inch each, between two glass sheets, .050 inch thick, making a total of 20 layers.

Curve a in Fig. 12b shows that for ordinary unpolarized light, the ratio r is approximately constant out to about 30 degrees, and equal to 5.2, then it decreases rapidly to 3.0 at 45 degrees and to 1.8 at 60 degrees.

Curve b in Fig. 12b shows that for light polarized with a multilayer polarizer, the ratio r always increases — at 30 degrees, it is 8.7, at 45 degrees it is 9, and at 60 degrees, it is 15.

Curve c, Fig. 12b shows the per cent increase in contrast ratio at each angle of incidence for light polarized by a multilayer polarizer, relative to ordinary unpolarized light — 75 per cent at 30 degrees, 175 per cent at 45 degrees and 730 per cent at 60 degrees. In terms of conventional contrast C, the per cent increase in contrasts at each angle is as follows:

Angle	Per Cent Increase C
0°	0
25°	9.3
30°	19.8
45°	31.5
60°	110

The contrast ratio is always greater with light polarized by a multilayer polarizer than with unpolarized light at all angles of incidence except the normal. Reducing this to contrast, the per cent increase is significant for greater angles of incidence for visual acuity. In fact, at the large

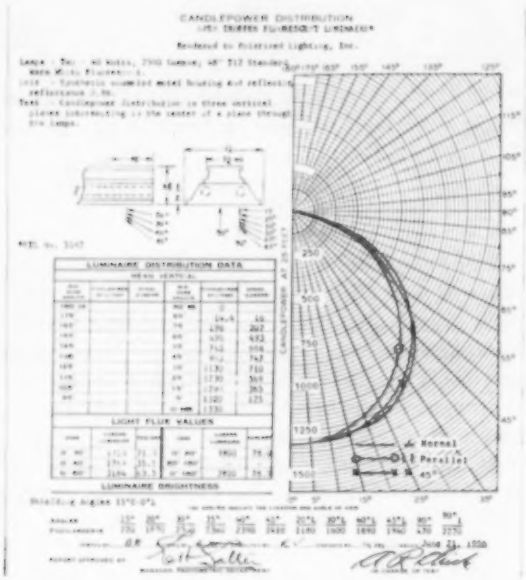


Figure 3a. Testing laboratory's report for open troffer fluorescent luminaire.

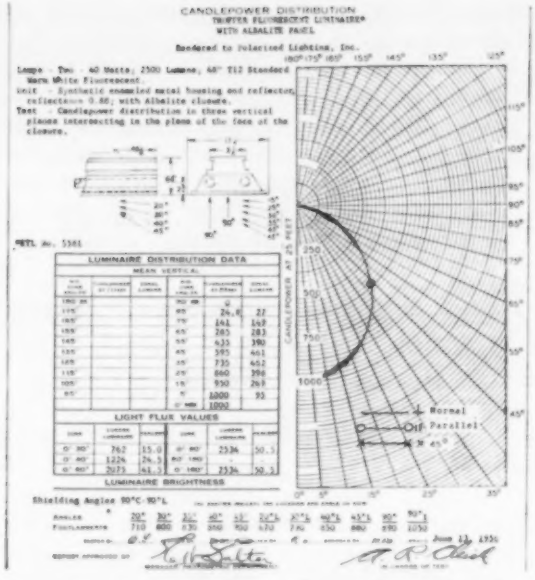


Figure 3b. Testing laboratory's report for troffer fluorescent luminaire with standard diffusing panel.

angles of incidence, the black and white areas, which are almost indistinguishable from each other in ordinary light, are in great contrast in polarized light, the contrast ratio at high angles being much better than the best obtained with unpolarized light which is at normal incidence. Therefore, it follows that the substitution of polarized illumination for unpolarized illumination will, in general, increase contrast, particularly at the wider angles of view. This, in turn, results in increased visual acuity around the room, as well as an increased visual perceptual threshold for objects.

Test Data

Intensity vs. Angle and Efficiency

Tests were made using a standard commercial troffer two-lamp fluorescent luminaire, open (without a shield), with a standard commercial diffusing shield, and with a multilayer polarizing panel now in commercial production. The multilayer polarizing panel was of the type using many random layers of flake glass with air interfaces. The tests shown in Figs. 3a, 3b, 3c, 5, 6, 7, 8 and 9 were conducted at the Electrical Testing Laboratory, Inc., New York, N. Y., an independent testing laboratory.

The tests shown in Figs. 3a, 3b and 3c show intensity *vs.* angle for (a) the unshielded luminaire, (b) the luminaire shielded with a standard type diffusing glass shield, and (c) the luminaire shielded with a multilayer flake glass type polarizing shield, respectively. Lighting efficiencies based on bare tube lumens are shown in the figures.

Fig. 3c shows that very much less light is transmitted by the flake glass multilayer polarizer panel between the angles of 70 and 90 degrees. Multilayer polarizing devices have an inherent low brightness at high angles, yet, light transmitted

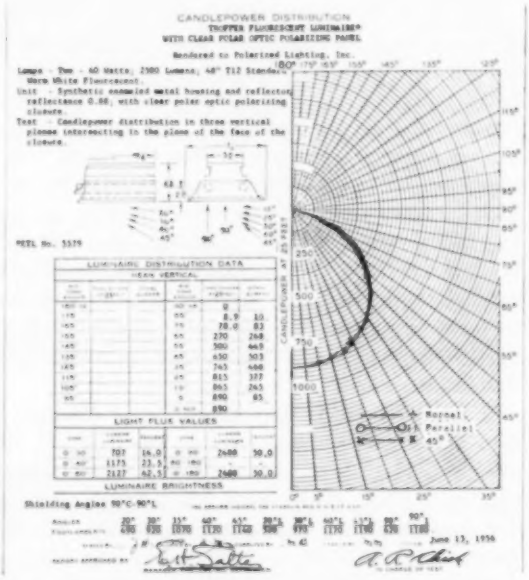


Figure 3c. Testing laboratory's report for troffer fluorescent luminaire with glass flake polarizing panel.

between the angles of 30 and 60 degrees is in excess of that transmitted by the standard diffusing shield, 3b. In Figs. 3a and 3b, there is greater candlepower projected downward under the luminaire. The downwardly transmitted light in the case of the multilayer polarized panel in Fig. 3c is less than that for the commercial diffusing panel shown in Fig. 3b, yet the light transmitted at the 35- to 60-degree angle is greater over the most important range of solid angles. The light flux values are approximately equal to 50 per cent for both the commercial diffusers and multilayer panels, compared to 78 per cent for the unshielded luminaire, an efficiency of 64 per cent relative to the unshielded luminaire taken as 100 per cent.

It is known[12] that higher contrasts require lower levels of illumination for the performance of visual tasks. Hence, since polarized lighting provides higher contrasts, with the same level of illumination, the visual effectiveness is increased.

Tests With Multilayer Plastic Polarizing Panels

Another series of tests was performed with 18 thin layers of plastic, .001 inch thick cellulose acetate, between two layers of clear glass, each about 0.125 inch thick, making a total of 20 layers as a panel under a standard commercial troffer fluorescent luminaire.

Fig. 15 shows candlepower distribution *vs.* angle for (a) unshielded luminaire, (b) luminaire with a standard frosted glass and (c) luminaire with the multilayer plastic polarizing panel. These results are plotted in Fig. 16 as zonal lumen distribution *vs.* angle.

The results show: (1) A suppression of the light in the 0- to 33-degree range; and (2) an increase in light flux as zonal lumens in the 33- to 70-degree range. These results are in general agreement, but accentuated relative to the tests previously discussed with the flake glass polarizers, and may be attributed to the reduced diffusion with plastic polarizers over the diffusion of the type of flake glass polarizers used in these tests. This is because the air spaces in the plastic polarizers were flat and uniform, while those of the flake glass polarizers were not.

The lighting characteristics of the multilayer polarizer shown in Figs. 3c and 15 are better adapted to produce to a wider and more uniform field of illumination. Polarized luminaires equipped with multilayer polarizers may be spaced somewhat wider apart and still give a more uniform light on the visual plane. This may be particularly important in view of the new high intensity fluorescent lamps now being introduced. Ceiling brightness would be reduced and luminaire spacing may be increased.

Whether the viewer is standing or sitting, except when viewing a specific visual task, the most useful angles of view lie between 30 and 60 degrees. The multilayer polarizer gives a more useful distribution of light in the 30- to 60-degree range than does the luminaire shielded with the commercial diffuser (3b). Because the multilayer polarizing sheet inherently provides a much lower transmission between the angles of 70 and 90 degrees, as shown in Figs. 3c and 15, low ceiling brightness results, and direct ceiling glare is either reduced or eliminated. The reduced intensity of the normally directed rays using the multilayer polarizer, shown in Figs. 11 and 15, smooths out the increased brightness usually present under the luminaire, and provides a more uniform field of illumination. These factors enhance the performance of multilayer polarizer shielding panels for general polarized lighting.

A room provided with general polarized illumination is psychologically pleasing. Under polarized light, there is a reduction of veiling haze on horizontal surfaces which results in improved visual clarity, increased visual threshold for objects difficult to perceive, increased saturation of colored objects and low ceiling brightness. Consequently, there is a feeling of ease and a reduction of fatigue with general polarized illumination.

Contrast Tests

Tests for contrast were made using black and white matte and black and white semi-gloss papers. Samples of each were chosen to give comparative measurements for contrasts from an open luminaire, from a standard diffusing shielded luminaire and from a luminaire shielded with the multilayer polarizer of the flake glass type. These measurements were taken on the apparatus shown in Fig. 4, which was designed and built to the author's specifications.

Instrument Used for Measuring Contrast

In this instrument, large areas corresponding to the object, such as black print, and large areas corresponding to the background, such as white paper, are measured separately.

81 — Luminaire capable of turning on axis A, NN′ normal to face of luminaire.

82 — Electrical measuring meter to measure light intensity in relative units (photovolt meter).

83 — Photocell equipped with iris diaphragm.

84 — Surface being tested.

85 — Lighting panel being tested.

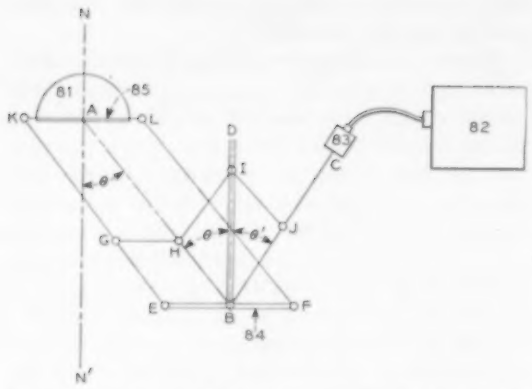


Figure 4. Mechanical linkage system for test in which the viewing plane is always parallel to the multilayer polarizing panel, and the angle of incidence is always equal to the angle of reflection.

Surface 84 is maintained parallel to lighting panel 85 by linkage KEFL, to simulate horizontal surface of desk (or floor) illuminated by horizontal panel 85 in ceiling, at all angles of incidence, θ.

DB is a slot guide perpendicular to surface 84 and GHEB — BIJ-BC is a linkage such that angle of reflection $\theta' = \theta$, angle of incidence, at all times. This corresponds to the most critical angle of viewing where glare is a maximum.

The per cent increase of the contrast was computed for the multilayer polarizing panel in terms of the standard commercial diffusing panel and also the open troffer. The above computations were made for both matte paper and newsprint paper.

Results of Contrast Measurements

Measurements plotted in Fig. 5 show contrast for black and white matte paper at various angles of incidence; those in Fig. 6 show contrast for black and white semi-gloss newsprint paper at various angles of incidence.

The contrast tests were conducted so as to produce the maximum specular glare. This corresponds to the most difficult visual condition, *i.e.*, when the viewer is so situated that the angle of reflection from the object equals the angle of incidence of the light on the object.

Figs. 7 and 8 show the per cent increase in contrast for black and white matte paper and for black and white semi-gloss newsprint respectively. Figs. 7 and 8 show that the per cent increase in contrast is always positive for all angles of incidence.

Thus, from the experimental data of Figs. 7 and 8, and from the theory from which equation (9) is derived, it is proved that compared to ordinary unpolarized light, for general illumination, polarized light always increases the contrast, consequently, polarized light has the collateral desirable effects of improved visual acuity, and improved visual threshold, *i.e.*, better visibility.

The maximum per cent increase in contrast is noted at or near Brewster's angle, where the percentage of polarization is maximum and the reflected component is minimum. However, the per cent increase in contrast of polarized light in comparison with unpolarized light is always positive at all angles of incidence. The only angular range

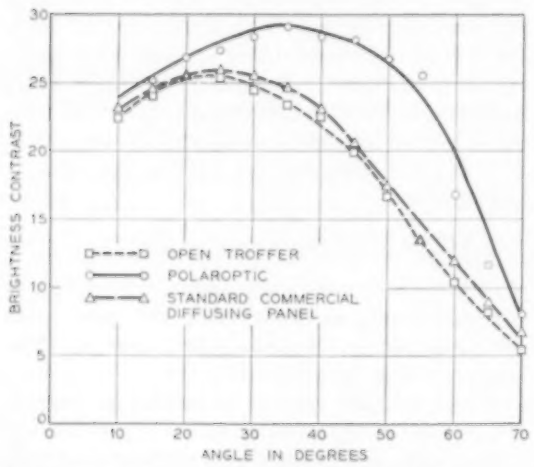


Figure 5. Brightness contrast of black and white matte paper when illuminated with a flake glass multilayer polarizing panel, compared to an open troffer and a standard commercial diffusing panel. (Note: Circles and solid lines indicate flake glass panel.)

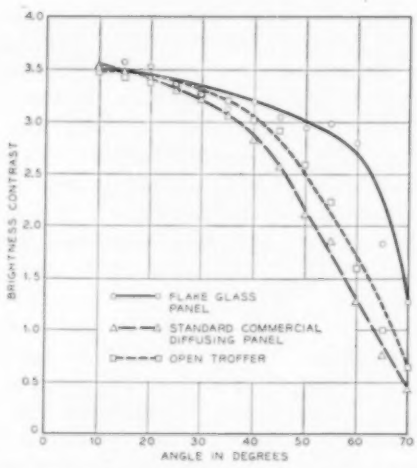


Figure 6. Brightness contrast of black and white newsprint when illuminated by a fluorescent troffer with a flake glass multilayer polarizing panel, an open troffer and a standard diffusing panel.

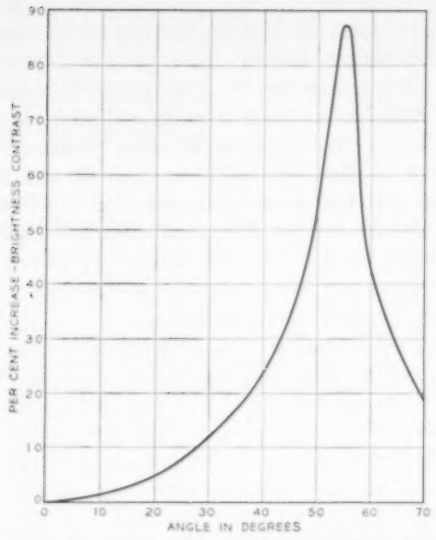


Figure 7. Per cent increase of brightness contrast of black and white matte paper when illuminated by a fluorescent troffer with a flake glass multilayer polarizing panel compared to a standard white diffusing panel.

where little or no change is noted is in the 0- to 30-degree range. This range is outside the range normally utilized except for viewing specific visual tasks.

TESTS — PER CENT POLARIZATION

The per cent of polarization from the flake glass multilayer polarizing panel was determined from nadir to 85 degrees when the panels were mounted in a two-lamp 40-watt fluorescent troffer. The per cent of polarization was based on candlepower distribution measurements made in a plane perpendicular to the plane of the fluorescent lamps. The measurements were made viewing the unit through a polarizing analyzer, first with the polarizing medium transmitting the maximum amount of light, and then with the polarizing medium rotated to give the minimum amount of light delivered to the photocell.

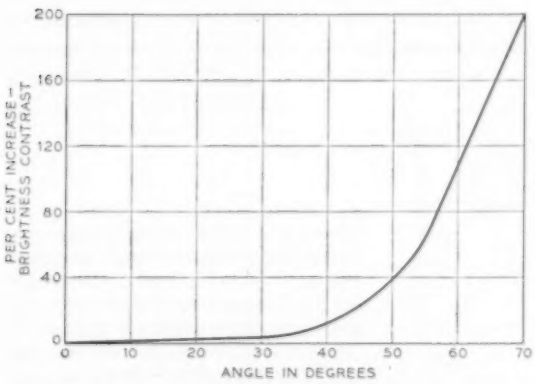


Figure 8. Per cent increase of brightness contrast of black and white newsprint paper when illuminated by a fluorescent troffer with a flake glass multilayer polarizing panel compared to a standard white diffusing panel.

The computations were made by the formula

$$\text{Per cent polarization} = 100\,\frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

Fig. 9 shows the results of a test made in connection with the multilayer polarizing flake glass panel on the variation of the percentage of polarization with the angle of the transmitted light from the luminaire. This shows that the percentage of polarization in this particular panel reached a maximum of approximately 85 per cent at or near Brewster's angle, approximately 57 degrees.

Veiling Haze — Reduction with Polarized Lighting

We now come to an important point relating to the invisible veiling haze, almost always present

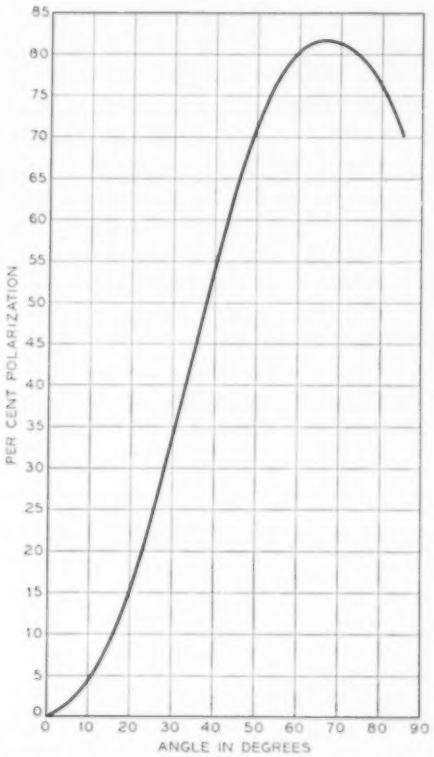


Figure 9. Per cent polarization *vs.* angle of incidence of a clear flake glass multilayer polarizing panel in a fluorescent troffer.

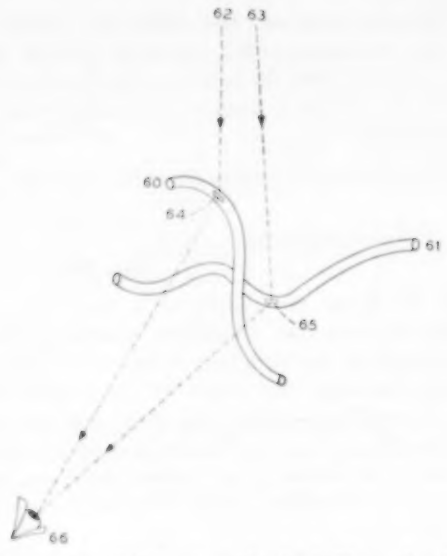


Figure 10. Idealized randomized fibers showing portions of surface of each fiber acting as specular reflecting areas.

with ordinary unpolarized light and reduced by the use of general polarized lighting.

It has been shown that contrast is always increased with the use of polarized lighting as compared with unpolarized lighting, at all angles of incidence of the light except the normal. This is true whether or not the measurements are made under conditions of the most difficult viewing.

Matte objects such as the surface of paper, rugs, clothing, desks, wooden floors, etc., comprise the majority of viewing tasks. Matte objects are composed of fibers running randomly in all directions. There is a proportion of specular glare from these random fiber surfaces regardless of the position of the surfaces, the light source or the viewer.

Fig. 10 shows any two rays, 62 and 63, proceeding from a light source (not shown) impinging upon the randomly directed fibers 60 and 61. Portions of the fiber surface which are shown as elementary areas 64 and 65 are randomly oriented so as to reflect, directly, the rays 62 and 63 to the eyes of the observer 66. The angles of incidence and reflection of these directly reflected rays are equal, and therefore, the situation obtained with respect to the elementary surfaces 64 and 65 is identical to that shown in connection with Figs. 2a and 2b. Therefore, the use of polarized lighting, as shown in Fig. 2b, will remove or reduce the specular glare component from the elementary randomly placed areas 64 and 65.

The great number of random specular reflections give rise to what may be termed "veiling haze," present everywhere. This "veiling haze" is reduced by the use of general polarized illumination. It has been demonstrated here that general polarized lighting utilizing multilayer polarizers as shielding panels for light sources will reduce "veiling haze" and will, therefore, increase visibility, contribute to visual comfort and lessen fatigue.

It will be apparent that the above principles also apply to luminous ceilings, which are more or less completely shielded by multilayer polarized panels.

A further important property of multilayer polarizing panels applied to illumination is shown in Fig. 11. This is the property of control of the light distribution curve by the employment of a fewer or greater number of layers of differing indices of refraction. In Fig. 11, curve 70 shows the light distribution pattern with 18 thin plastic layers plus two sheets of glass, totalling 20 layers, having an index of approximately 1.5, alternating with air of index approximately 1.00 for transmitted light only. The plastic layers employed were thin (.001-inch thick), cellulose acetate sheets between .050-inch thick glass supporting layers.

Curve 71 shows the light distribution curve for the same structure, but with 38 thin plastic layers and 2 sheets of glass, totalling 40 layers. Increase in the number of layers is effective in increasing

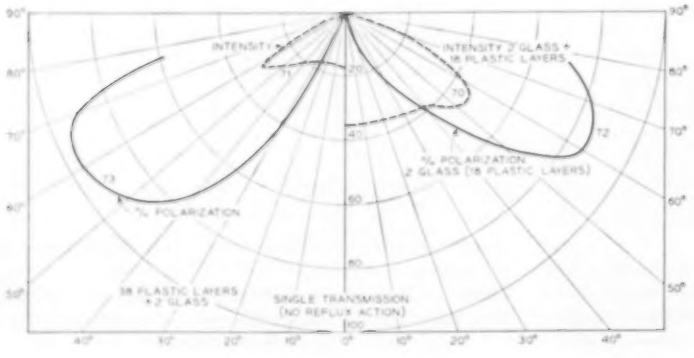

INTENSITY 2 GLASS + 18 PLASTIC LAYERS
% POLARIZATION 2 GLASS (18 PLASTIC LAYERS)
% POLARIZATION
18 PLASTIC LAYERS + 2 GLASS
SINGLE TRANSMISSION (NO REFLUX ACTION)

Figure 11. Polar graph showing per cent transmission and per cent polarization of light vs. angle of incidence for multilayer plastic polarizers supported by glass, having a total of 20 layers and 40 layers, respectively, with no reflux action.

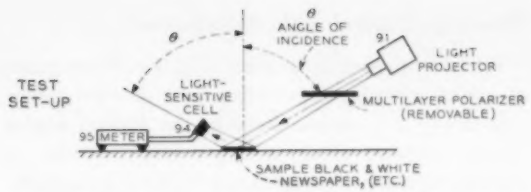


Figure 12a. Test set-up for Figs. 11 and 12b. (Note: Number 93 should be inserted before "sample black and white newspaper" — viewing area.)

the ratio of transmission at Brewster's angle relative to the transmission at normal incidence, in the case of curves 70 and 71, from 1.27 to 1.61. With a sufficient number of layers, it is possible to suppress normal transmission almost entirely, while permitting transmission at Brewster's angle. Curves 72 and 73 are the corresponding curves showing polarization *vs.* angle for the 20 and 40 layers respectively. The effect of increasing the number of layers is to increase the percentage of polarization at all angles of incidence and to broaden the angular distribution of polarization, that is, to increase the percentage of polarization at all angles of incidence except at 0 degrees.

Results of Calculations on Multilayer Polarizers Using Fresnel's Equations

Fig. 13 shows a graph constructed by the author,[11] from calculations based on Fresnel's equations, for multilayer polarizers with various numbers of layers and various relative indices of refraction assuming no absorption. These show:

(a) The transmitted light at the normal or 0 degrees may be reduced almost zero by at least 80 layers of index 1.41, 32 layers of index 1.73 or 16 layers of index 2.24.

(b) The peak transmission at Brewster's angle is 50 per cent (assuming no absorption losses) regardless of the number of layers or the index of refraction.

(c) At any given index of refraction, the per cent polarization curve rises more rapidly using a greater number of layers. For example, to obtain at least 95 per cent polarization at 30 degrees or more, we may use 80 layers, N = 1.41, 32 layers, N = 1.73 or 16 layers, N = 2.24, while the 95 per cent polarization is obtained at 57 degrees or more with 20 layers, N = 1.41, 8 layers, N = 1.73 or 4 layers, N = 2.24.

(d) Brewster's angle shifts from 54 degrees at N = 1.44 to 57 degrees at N = 1.50, to 60 degrees at N = 1.73, to 67 degrees at N = 2.24.

For general illumination, I prefer to use materials such as glass or plastic which have a relative index of refraction of approximately 1.50, which corresponds to the same index 1.50 for paper, wood, glass and the most commonly viewed objects.

Polarized Halo Effect

Fig. 14 shows a ceiling equipped with a sufficient number of layers to produce the "polarized halo ceiling" effect. With a sufficient number of layers, it has been shown, experimentally and theoretically, in Figs. 11 and 13 respectively, that the downward light in the 0- to 30-degree range may be almost totally suppressed, while practically complete polarization of the transmitted light may be achieved using at least 80 layers of index 1.41, 32 layers of index 1.73 or 16 layers of index 2.24. My preference is for at least 80 layers and index 1.50.

Application of the Polarized Halo Effect To Viewing Specific Tasks

While the principles discussed in this paper have been applied to general illumination, the author suggests a solution to the problem of viewing specific tasks, such as pencil marks on paper, which show reduced contrasts due to specular reflections in the 0- to 45-degree range and having a maximum at 25 degrees.[12]

If a ceiling is constructed in this manner, a halo of polarized light will appear to form a circle of

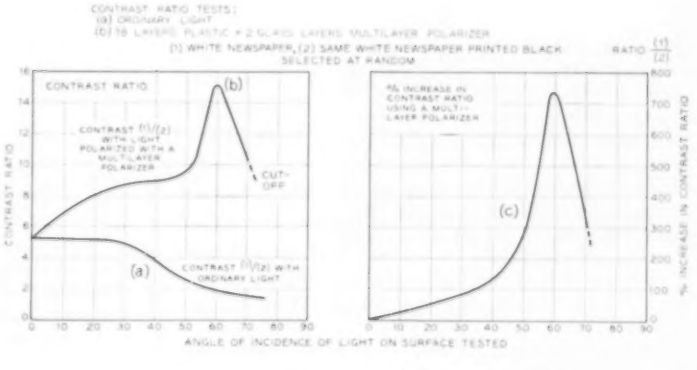

CONTRAST RATIO TESTS:
(a) ORDINARY LIGHT
(b) 16 LAYERS PLASTIC n = 2.5 GLASS LAYERS MULTILAYER POLARIZER
(1) WHITE NEWSPAPER, (2) SAME WHITE NEWSPAPER PRINTED BLACK SELECTED AT RANDOM
RATIO (1)/(2)
CONTRAST RATIO
(b)
CONTRAST (1)/(2) WITH LIGHT POLARIZED WITH A MULTILAYER POLARIZER
CUT-OFF
(a)
CONTRAST (1)/(2) WITH ORDINARY LIGHT
% INCREASE IN CONTRAST RATIO USING A MULTILAYER POLARIZER
(c)
% INCREASE IN CONTRAST RATIO
ANGLE OF INCIDENCE OF LIGHT ON SURFACE TESTED

Figure 12b. Contrast ratios for unpolarized light (a), for polarized light using multilayer plastic polarizer (b), and per cent increase in contrast ratio using a multilayer plastic polarizer compared to unpolarized light vs. angle of incidence of light on the surface tested, for black and white newspaper (c).

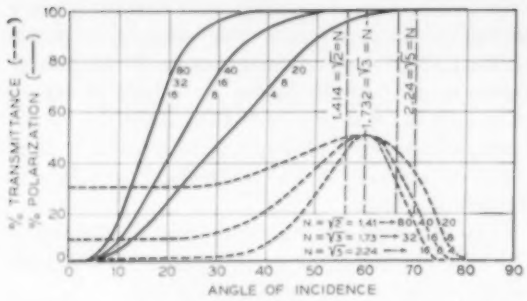


Figure 13. Theoretical calculated curves showing variation in per cent transmittance, and per cent polarization, *vs.* angle of incidence, with no reflux action, and with different numbers of layers and different relative indices of refraction. Peak transmission is achieved at Brewster's angle indicated according to the relative index of refraction.

light 101 on the ceiling 100, with the observer at the apex. This halo of polarized light will follow and surround the observer no matter where he might be in the room.

The polarized halo ceiling effect is extremely useful in solving the visual task problem[13] by suppressing light in the 0- to 45-degree range, particularly light at 25 degrees, and providing, instead, an inverted cone of polarized light from the halo as the base of the cone and the polarized halo ceiling light surrounding the task area 102 at the apex of the cone. It will now be obvious that the rays near 57 degrees will be refracted into the surface 102 and very high contrasts will result, as shown in curve b, Fig. 12b. Also any residual specularity will be reflected as beam 106, at angles of reflection equal to about 57 degrees, and thus will avoid contact with the observer's eye at 105, which tends to pick up reflections mostly at 25 degrees when working at a specific task area 102, such as a desk.

Prismatic Control with Polarization

Suitable prismatic control applied in conjunction with multilayer polarizers can provide a concentration of polarized light at the desired angles on the working plane, with resultant increase in visual performance, contrast and color saturation.

Summary and Conclusions

1. Multilayer polarizers are uniquely adaptable to providing general and specific polarized lighting because of the following characteristics:

(a) Radial polarization.

(b) Reflux polarization action yielding a high efficiency in the conversion of ordinary unpolarized light to polarized light. Tests showed the efficiencies achieved to be comparable to those achieved with commercial diffusing panels.

(c) Low ceiling brightness tests showed a useful transmission cut-off between 70 and 90 degrees for the multilayer polarizing panel.

(d) Reduction or suppression of light transmitted at 0 to 45 degrees.

2. A new apparatus for measurement of contrast is described (see page 129). Tests were made with black and white matte and black and white semi-gloss newspaper.

3. Theory and tests show contrast always to be greater with polarized light at all angles of incidence, reaching a maximum at or near Brewster's angle. The increase of contrast with polarized light is related to increase of visual acuity and to increase of perceptual threshold, as well as to improved color perception.

4. Data are presented on percentage of polarization and intensity *vs.* angle, with the multilayer flake glass panel (see page 128).

5. Data are presented on intensity and zonal lumens *vs.* angle for a 20-layer multilayer plastic polarizer (see page 129).

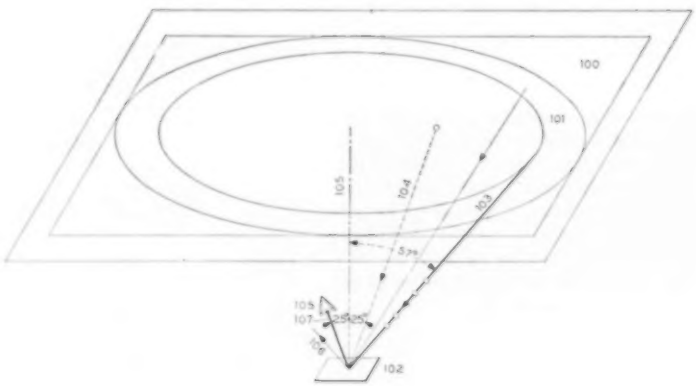


Figure 14. Appearance of multilayer polarized ceiling halo effect and the angles involved with reference to the average viewing angle of 25 degrees for a task, showing how angle of incidence of 57 degrees results in a reflection outside the viewing angle of 25 degrees, thus reducing specular glare, apart from the total refraction phenomenon.

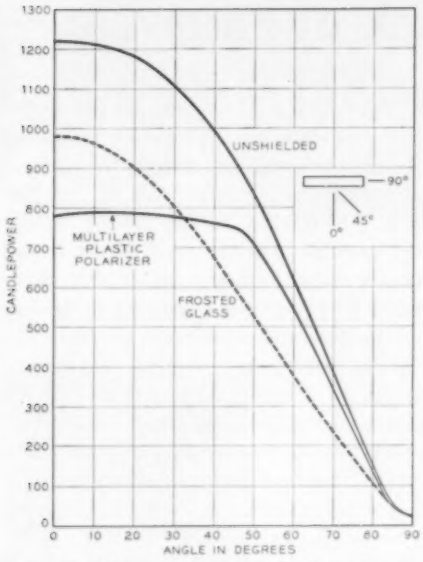


Figure 15. Candlepower vs. angle in degrees for a 16-layer multilayer plastic polarizer in a two-light troffer, supported between glass (18 layers total), compared to the unshielded troffer and to the same with a standard frosted glass panel.

6. Further tests and theory show that the distribution characteristics of both the intensity and percentage of polarization *vs.* angle of incidence could be controlled by varying the number of layers and their relative index of refraction.

7. Presence of veiling haze everywhere with ordinary unpolarized light is discussed, and the reduction of veiling glare with polarized light is established.

8. The "polarized halo ceiling" effect is discussed, and its application in elimination or reduction of specular glare from the viewing task is demonstrated.

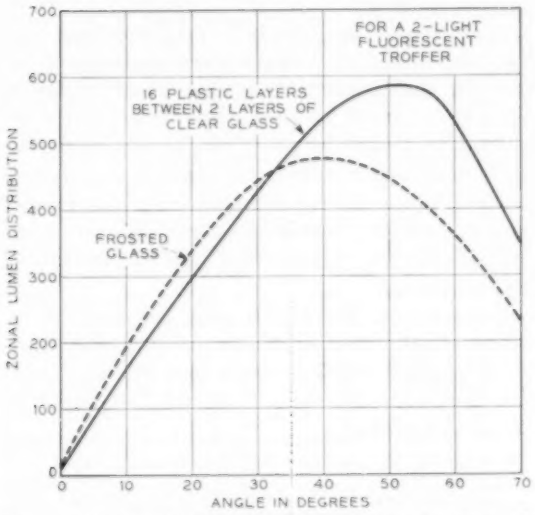

ZONAL LUMEN DISTRIBUTION
ANGLE IN DEGREES
FOR A 2-LIGHT FLUORESCENT TROFFER
16 PLASTIC LAYERS BETWEEN 2 LAYERS OF CLEAR GLASS
FROSTED GLASS

Figure 16. Zonal lumen distribution for the data of Fig. 15, showing comparison for a 16-layer multilayer plastic polarizer supported between two glass panels, compared to a standard frosted glass panel.

Acknowledgement

The author wishes to express great appreciation to his associate, Mr. Myron Kahn, President of Polarized Lighting, Inc., for his contribution to this work. Mr. Kahn, by his dedication to this project and tireless energy has made possible the introduction to illumination of this new and fundamental factor — control of the direction of light vibration of the light flux known as polarization — which presages a new era and broader vistas for the lighting industry.

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Errata

Vol. LIII, No. 12, page 678 — Philip F. O'Brien's discussion of paper by Edward Linforth.

The term $F^2\ (1-\rho_1)$ in the denominator of Equation (2) should read $F\ (1-\rho_1)$. That is, the term F is *not* squared.

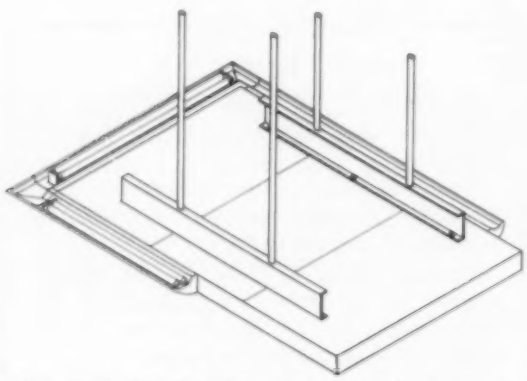
Several values in Table A are affected slightly by this correction of Equation (2). The changes are not significant and do not change the sense of the discussion.

Bank of Farmville

NATIONAL ENTRY
CLASS II

mi lj

Cross-section of center bay and two side bays.



Three luminaires bolted together and perimeter coves.

REQUESTS by bank directors for re-lighting programs are often accompanied by the stipulation that, in modernizing, no change be made in the period architecture. So it was at the Bank of Farmville (Farmville, N. C., pop. *c.* 3000), constructed in 1920. The building, of reinforced concrete, has a 21-foot ceiling height and massive beam construction. Scalloped cornices embellish the soffit perimeters and marbleized surfaces are used for columns and tellers' counters. Skylights in the ceiling provided little in the way of illumination and west wall windows contributed mainly glare.

An early decision was to cover the skylights with wall board matching the adjacent ceiling. Soffits in the center bays are about 18 inches deeper than those in the side bays. This meant that there was no method of wiring to a center suspension except on the surfaces of the ceiling. On the other hand, the depth of the side-bay soffits made mounting supports a problem.

Coves were chosen for the center bays, to be level with the side-bay fixtures and to serve as wiring troughs for them. Fixtures in the side bays provide downlight from three 2- by 4-foot plastic-shielded luminaires strapped together with channel iron. Four side sections of polished aluminum cove are bolted on and corner plates added, to give a composite fixture of 5 by 7 feet. The perimeter coves in these units provide the necessary uplight to highlight the cornice detail, as do the coves in the center bays.

A section of the false ceiling in side bays was cut away enough to permit a workman to get at the concrete slab above to secure the hanger rods. A one-piece canopy, of 28 by 40 inches, was then fabricated locally to cover the ceiling openings. Lock-nuts on the hanger rods support the canopy.

Each luminaire section uses four fluorescent lamps above the plastic shielding and each cove section uses two. Illumination level in the lobby is 60 footcandles.

The original chandeliers, with diffusing bowls, were retained, keeping the flavor of the architectural design. The iron cages around the tellers' positions were removed and columns were repaired and re-marbleized.

Coy C. Jordan, *Carolina Power & Light Co., Raleigh, N. C., tied for first prize in the Southeastern Regional Contest for MMILJ, having placed first in the Tar Heel Section.*

LIGHTING NEWS

George H. Stickney Dies — IES Charter Member

George H. Stickney

George H. Stickney died Friday afternoon, December 19, following a short illness at his home in Daytona Beach, Fla. He was 86 years old.

Mr. Stickney, affectionately known as "Uncle George" by lighting engineers throughout the world, was for many the "dean" of the illuminating engineering profession. He was one of the founders of the Illuminating Engineering Society in 1906, and a Charter Member. When the IES Gold Medal was established in 1944 as the top honor in illuminating engineering, Mr. Stickney was chosen as its first recipient.

Mr. Stickney at one time or another had been a member of most of the Society's committees, and served as President of the Society in 1917.

Mr. Stickney was born in Buffalo, N. Y., in 1872 and was graduated from Cornell University in 1896. He joined the General Electric Co. at Schenectady in that year and for the next forty-one years devoted his career to the development and science of electric illumination. A pioneer in the development of light sources and their application, Mr. Stickney is credited with the design of the radial wave reflector for street lighting in 1906, the first semi-direct fixture for the incandescent lamp, and the creation of the first systems of floodlighting, including the illumination of Niagara Falls. He did much original work in photometry and in the design of arc lamp equipments at both the Lynn and Schenectady plants of General Electric. He became a consulting engineer for the Nela Park Engineering Department of the company in 1930, and retired in 1937.

For the twenty-odd years since his retirement, Mr. Stickney remained a much-sought advisor in the industry, and in the affairs of the Society. He continued active on several IES committees, and was a familiar figure at all National Technical Conferences until 1958.

In addition to his work with IES, Mr. Stickney was a Past-President (currently Honorary President) of the United States National Committee of CIE, and a member of its Executive Committee, a Fellow in the American Institute of Electrical Engineers, a member of the American Association for the Advancement of Science, and a member of Kappa Sigma, honorary society of Sigma XI.

He is survived by his sons David W., of Lake Forest, Illinois, George Jr., of Paterson, New Jersey, and David's three children.

Plans are underway by the Historical Committee of IES leading to the establishment of a Memorial Fund for George H. Stickney, possibly to support a suitable memorial library or other service memorial of that nature.

George Stickney — Pioneer Educator

In the passing of "Uncle George" Stickney, the lighting fraternity has lost a Founder Member of the Illuminating Engineering Society, and a distinguished Past-President whose inspirational leadership was invaluable in his earlier active years. His dedicated voice of hope and prophecy is happily recorded for posterity. The Historical Committee preserves the disc record of probably his last formal talk to his great host of friends!

Among the many characteristics for which George Stickney will be long remembered, I regard his achievement as a pioneer educator to be the outstanding one. As a young engineer he had moved from Lynn, Mass. (where he developed the practical use of the sector disc in the photometry of chiefly street lighting units in W. D. A. Ryan's lighting laboratory) to the Edison Lamp Works of General Electric, at Harrison, N. J. There he set up lighting demonstration rooms and gathered together a group of young men whom he inspired and taught to later become leaders in the blossoming illuminating engineering profession.

Among these were such pioneers as Al Powell, Larry Porter, Ed Fox, F. J. Gray, Jack Summers, Ed Harrington, W. H. Rademacher, Art Oday, Archie Bell, Freeman Barnes, Scotty Turner, Henry Schroeder, John Kurlander, R. W. Peden, Carew Sheldon, R. B. Kellogg, G. F. Prideaux, Bill Hadaway, Greiner and Roy — all these and still other good men (and some remarkable women) who have carried forward the fundamental virtues of ingenuity, exactness and honest engineering that were the foundations of George's Quaker principles.

These men were authors of a series of lighting Bulletins that were exceedingly popular during the general period of 1920-1925. Such bulletins or booklets — there were several dozen — specialized in "practice methods," and much of their contents remain fundamental "gospel" even until today!

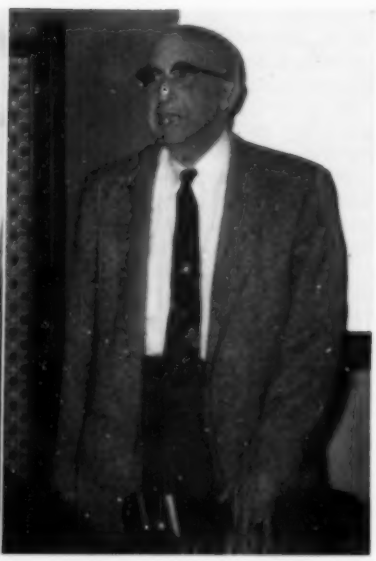
Further back, this teaching method of issuing "how-to-do-it" booklets had begun with Bulletin No. 1, January 14, 1907, describing the Engineering Department of the National Electric Lamp Association, in Cleveland. That group of five incandescent lamp manufacturers

(Continued on page 9A)

Here and There With I.E.S. Members

New Orleans Section Joint Meeting with architects and consulting engineers featured I.E.S. Technical Director C. L. Crouch (see photo below), speaking on the Blackwell studies.

Head table at the New Orleans meeting (photo above) shows, from left to right, Walter T. Faber, past Section Chairman; Mrs. J. M. Gensburger; J. M. Gensburger, South Central Regional Veep; Mrs. George Segal; George Segal, Program Chairman; C. C. Kleinschmidt, Section Chairman; C. L. Crouch, I.E.S. Technical Director; Mrs. George Schroeder and George Schroeder, third prize winner in Class I of the 1958 MMILJ contest.



Speakers at recent Southern California Section meeting were, from l. to r., Bob Clubley, who discussed problems in selling the new recommended levels; F. H. Martin and F. W. Weymouth, who spoke on various aspects of color.

(*Continued from page 7A*)

(which soon grew to 19), distributed some 3000 copies of that bulletin.

By the autumn of 1913 the popularity grew apace. Now under the masthead of the National Lamp Works of General Electric, plus two subsidiaries — Holophane and Tungstolier Companies — this method of education was established for both professional and lay users of light.

One typical Bulletin, No. 7 of June 1, 1907, provided illumination data that was "the bible" for several years. One leading illuminant described was the tantalum lamp, burning nearly 600 hours at 2 watts per candle, price 54 cents.

Nearly 60 bulletins were issued (in Cleveland), up to October 1929, after which the publication died away.

But the Stickney group at Harrison had still further exemplified, ten years before, just how this dissemination of knowledge was to advance lighting practice immeasurably.

Concurrently with the issue of these publications, there was the famous "Lighting Practice Committee," that met three or four times annually, and where the footcandle standards plus many other practices were settled upon by Mazda and licensed lamp makers. George Stickney for many, many years was its conscientious chairman.

Thus a pioneering manufacturer's literature was spread abroad, establishing the lighting standards and methods of this youthful industry — and as Uncle George's young scientists carried torches of learning far and wide — the practical, applied science of illuminating engineering grew to maturity.

The lengthening shadow of this kindly educator lies gently across our proudest memories.

The first sentence of George Hoxie Stickney's epitaph should read — "He taught the pioneering practices of illumination with prophetic imagination and vision, and he inspired young leaders of lighting science with zeal and forthrightness."

SAMUEL G. HIBBEN

Two-Part Lighting Course Offered Concurrently in Montreal

Two courses, designed to provide essential theory (Illumination I) and fundamental background necessary for all types of lighting design (Illumination II), are being offered jointly by the Toronto Section of IES and the University of Toronto Extension Service. Both courses are intended for those directly concerned with illumination design in their day-to-day work. Material contained in Illumination I is regarded as necessary background for Illumination II, which will be offered again next year.

Topics and lecturers are:

Illumination I

January 6 — Nature and Production of Light — Miss M. G. Currie
January 13 — Vision; The Eye — Dr. J. G. Ogilvie
January 20 — Vision; The Task — Dr. J. G. Ogilvie
January 27 — Lighting Terms and Laws of Illumination — G. E. Davidson
February 3 — Measurements — G. E. Davidson
February 10 and 17 — Flux, Illumination and Brightness Calculation — Prof. V. L. Henderson
February 24 — Control of Light — A. Birkhoff
March 3 — Illumination for Seeing; Quantity and Quality — H. F. Davidson
March 10 — Source Characteristics — H. C. Jones

Illumination II

January 7 — Basic Lighting Design — Miss M. G. Currie
January 14 — Basic Lighting Design Problems — Miss M. G. Currie
January 21 — Wiring — J. Chisvin
January 28 — Wiring Problems — J. Chisvin
February 4 — Lighting Economics — Bruce Quan
February 11 — Architectural Coordination
February 18 — Daylight Design Principles — H. F. Davidson
February 25 — Brightness and Glare — G. E. Davidson
March 4 — Problems Involving Vision at Low Levels of Illumination — Miss M. G. Currie
March 11 — Light, Colour and Human Beings

Classes are being held in the Engineering Building of the University. Because of the emphasis placed on open discussion, enrollment in both courses has been limited to 40. Course director is Miss M. G. Currie, Department of Applied Physics at the University. Norman Bethune of the Toronto Section is Chairman of the committee. Fee for each course: $15.

Symposium to Highlight National Lighting Exposition

Theme is "New Dimensions for the Footcandle"

One of the most stimulating events in any industry is a round-up of experts to discuss trends, current practice, how it may be applied, and how it may be of value to the industry's practitioners. Just such an opportunity is occurring in connection with the National Lighting Exposition, to be held at the Coliseum, New York City, on March 1 to 4. In addition to some 200 exhibits of the latest in lighting equipments, the show will feature 12 panel discussions on pertinent aspects of lighting practice. Another feature of the Exposition will be a 1000-seat theatre, within the Coliseum, for the showing of "How to Sell Lighting," a film produced by the Academy of Lighting Arts. Advance registration indicates attendance will be about 20,000 from all parts of the country.

Following the Keynote Address, to be delivered by IES President George J. Taylor, at 2:30 p.m., Sunday, March 1, panel discussions with open forum questions-and-answers will be:

Monday, March 2

Where Are We Going in Lighting
Moderator, C. M. Cutler, General Electric Co., Cleveland, Ohio.
Panel: C. M. Cutler; Abe H. Feder, Lighting by Feder, New York, N. Y.; Dr. S. G. Hibben, Consulting Engineer, Montclair, N. J.; J. Gordon Carr, Architect, New York, N. Y.

Office Lighting
Moderator, R. G. Slauer, Sylvania Electric Products Inc., Wheeling, W. Va.
Panel: John W. Hamilton, Day-Brite Lighting Inc., New York, N. Y.; W. S. Fisher, General Electric Co., Cleveland, Ohio; James F. Finn, Detroit Edison Co., Detroit, Mich.

Street and Highway Lighting
Moderator, Harold Mason, Street Lighting Engineer, City of Philadelphia, Pa.
Panel: Joseph D. Barnett, Deputy Assistant Commissioner, U. S. Bureau of Public Roads; Bruce Jensen, Public Service Gas & Electric Co., Newark, N. J.

Light and Architecture
Moderator, Burton Holmes, Editor, *Progressive Architecture*, New York, N. Y.
Panel: Richard Kelly, Lighting Consultant, New York, N. Y.; William Zeckendorf, Jr., Architect; Burton Holmes.

Tuesday, March 3

Institutional Lighting
Moderator, Kenneth Welch, Architect-Lighting Consultant, Grand Rapids, Mich.
Panel: Svend W. Bruun, Consulting Engineer, Ridgewood, N. J.; Henry Wald, Consulting Engineer, Wald & Zigas, Long Island City, N. Y.; Anton Parrison, Peter-Muller-Munk Associates, Pittsburgh, Pa., and Kenneth Welch.

Lighting for Selling and Color
Panel: Morris Ketchum, Architect, New York, N. Y.; Rollo Gillespie Williams, Century Lighting Inc., New York, N. Y.; Alfred Makulec, Store Lighting Expert, General Electric Co., Cleveland, Ohio.

Polarization — Its Relation to Lighting
Speaker — Alvin Marks, Polarized Light-Alsynite Corp., Whitestone, N. Y.

The Blackwell Report
Speaker, C. L. Crouch, Technical Director of IES.
Panel: Joseph S. Schuchert, Duquesne Light Co., Pittsburgh, Pa.; Morris Ketchum, Architect, New York, N. Y.; Prof. E. M. Strong, Cornell University, Ithaca, N. Y.

Wednesday, March 4

New Ideas and New Techniques in Residence Lighting
Moderator, Rose Coakley, Moe Light Co., Louisville, Ky.
Panel: Myrtle Fahsbender, Residential Lighting Director, Westinghouse Electric Corp., Bloomfield, N. J.; Thomas Smith Kelly, Lighting Consultant, New York, N. Y.; Melanie Kahane, Interior Designer, New York, N. Y.; William F. Blitzer, Lightolier Co., New York, N. Y.

Industrial Plants and Factories
Moderator, George J. Taylor, Vice-President, Day-Brite Lighting Inc., New York, N. Y.
Panel: Gerald C. Quinn, Editor, *Factory Management*, New York, N. Y.; L. G. Parks, Ebasco Services Inc., New York, N. Y.; Daniel J. O'Neill, Holophane Co., Inc., New York, N. Y.

(*Continued on page 12A*)

"I'M NO ARCHITECT OR ENGINEER,
BUT I DO KNOW THIS —
SMITHCRAFT LARGE ELEMENT
LIGHTING IS THE
BIGGEST THING THAT'S HAPPENED
IN THE LIGHTING INDUSTRY
IN YEARS!"

"I HAVE BEEN ASKED TO SAY
A FEW WORDS ABOUT
NEW SMITHCRAFT LARGE ELEMENT
LIGHTING . . ."

. . . suffice to say, it's the easiest
big fixture to install
on the market!"

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RE/LIGHTING

ANOTHER SMITHCRAFT FIRST!

Smithcraft Large Element Lighting
. . . a large area luminaire with POWER-GROOVE Lamps!
For more effective high level illumination in department stores, offices, laboratories, etc.

A "FLOATING" CEILING.
With five different sizes of units, a wide variety of areas and patterns are possible. Modules have exact dimensions in both directions.

Smithcraft large element lighting

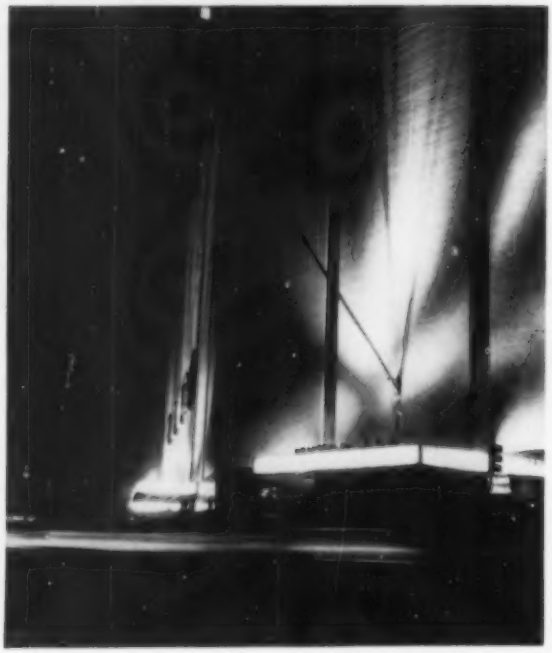
The "big idea" in lighting — to fit your own big ideas for the new and different in modern architectural settings! Simplified planning . . . with 5 sizes of *preassembled* modular units from 4′ x 4′ to 8′ x 6′. Modules are installed individually or joined in both directions, to provide the effect and the utility of dropped ceiling construction at low cost. High level illumination, architectural in form . . . functional and unobtrusive. Shielded by Holophane Controlens® #6024, Cubex aluminum ½″x½″x½″ louvers, Plastic louvers, or Polystyrene Plastic dishes. Fast, simple maintenance and re-lamping.

Write today for the Smithcraft Catalog

Smithcraft Lighting CHELSEA 50, MASS.

America's finest fluorescent lighting

® Holophane Company, Inc.



New York Coliseum, the site of the National Lighting Exposition, March 1-4, is appropriately itself an example of how lighting is now being used to complement the architectural designs of important buildings. A total of 118 300-watt PAR56 reflector lamps, is mounted along the top of the marquees, aimed at the flat-surfaced facade. Each lamp is enclosed in a cast custom-made aluminum housing, according to specifications from lighting consultant Abe Feder. The weather-proof fixtures are equipped with correcting lenses and may be adapted with color filters for special lighting effects. Photo and data courtesy of The Simes Co., College Point, N. Y.

(Continued from page 9A)

Outdoor and Recreational Lighting

Introduction, Harold Meyer, Manager NLE.
Panel: Merle E. Keck, Westinghouse Electric Corp., Cleveland, Ohio; R. C. Faucett, General Electric Co., Hendersonville, N. C.; Roscoe B. Mackenna, University of California.

Theatre and Television Lighting

Moderator, Robert W. Dowling, President, City Investment Corp., New York, N. Y.
Panel: Nathan Sonnenfeld, Theatre Lighting Designer; Joel Rubin, Kliegl Brothers Inc., New York, N. Y.; Peggy Clark, Theatre Lighting Designer, New York, N. Y.

Due to the interest in the symposium from within the lighting industry itself and such correlated professional people as interior designers, architects, contractors, builders, industrial designers, etc., no one will be admitted without prior reservations. Tickets are now available at the show headquarters, National Lighting Exposition, 550 Fifth Avenue, New York 36, N. Y.

Aviation Ground Lighting Committee Meets in Bangor, Maine

Approximately 80 Army, Air Force and Navy members of the Airline Pilots' Association, the Air Transport Command, and CAA, as well as officials from Canada, Sweden and Great Britain, met for a two-day conference with the Aviation Ground Lighting Committee of IES. Chief topic of discussion was the factor of all-weather flying. While there the group had an opportunity of inspecting Dow AFB's new combination Strobe and Elfaka lighting systems.

R. J. Stefany, Chairman of the Ground Lighting Committee, conducted the Tuesday sessions, when Dr. R. H. Jordan, director of the Research and Development Bureau of the Federal Aviation Agency, explained the set-up of this new organization, and the study of Hi-Speed turnoff tests being conducted at the University of California.

E. A. Cutrell spoke on the problems and work of airport visual aids, and Dr. H. Richard Van Saun discussed the physiological and psychological factors and their effect on a pilot. L. C. Vipond discussed the FAA's research and development program.

Sessions were also devoted to the various operational agencies' needs.

(Lighting News continued on page 15A)

Bangor Daily News

AVIATION Ground Lighting Committee and guests in Bangor, Maine, l. to r.: Dennis Bull, assistant Air Attache of Great Britain; Major Kjell Lagerstrom, assistant Air Attache at the Swedish Embassy; John P. Wilson, chief of the Electrical Engineering Department of the Canadian Air Transport Services; Martin A. Warskow, Chairman of the IES Aviation and Signal Lighting Committee; R. J. Stefany, Chairman of the IES Ground Lighting Committee; Dr. H. R. Van Saun of the Research and Development Board of FAA; and Col. George W. R. Zethren, commander, 4060th Air Refueling Wing at Dow AFB.

nething *Really* Different in Fluorescent Lighting

Sabre by Miller is a fresh, exciting approach to the design concept of *on-the-ceiling* fluorescent lighting. Here, shallow depth and sweeping lines blend to enhance the appearance of any interior. Styling, comfort and high efficiency meet the needs of modern stores and offices — commercial interiors of all kinds; schools, too.

Sabre's carefully engineered, *one-piece* wrap-around refractor of prismatic, crystal-clear plastic provides added sparkle, and excellent brightness control. Viewing is comfortable from all angles. Maintenance is easy.

And this unique combination of features comes at a truly popular price. Discover today, how the new Sabre can help solve your specific lighting design needs. Write Dept. 958-A, The Miller Company, Meriden, Conn. for complete catalog information, or contact your Miller Representative for a physical demonstration.

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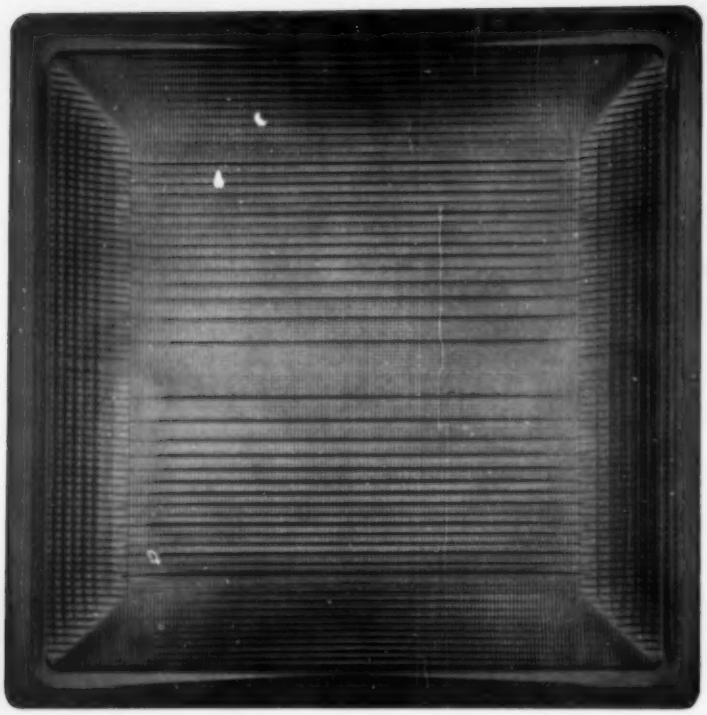
SINCE 1844



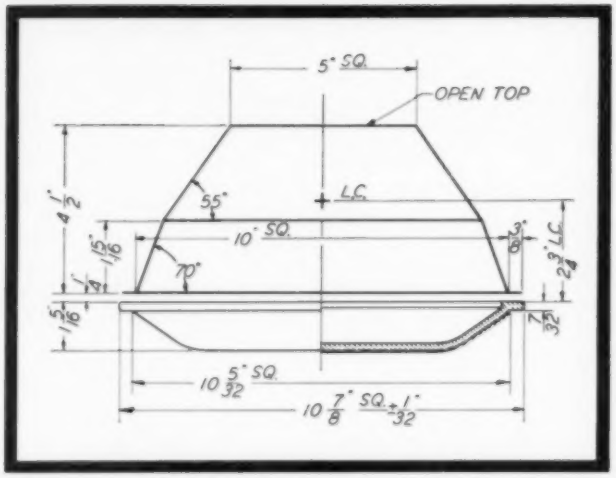
From Corning a new Tempered Corridor Lenslite

This new Corning *Tempered* Corridor Lenslite is both rugged and versatile.

Tempered for heat and impact resistance, it's three times as strong as ordinary annealed ware. You can use it indoors or out—with lamps to 300 watts—without fear of breakage.

With its unusual light distribution—two beams along a corridor plus supplemental side-wall illumination—you'll find it just right for use in lighting of corridors, aisles, entries, display areas, library stacks and storage bins.

You get this double-function lighting by using the Corning No. 543021 *Tempered* Corridor Lenslite with the C-201 Specular Alzak Reflector. Designed to operate as a *unit*, Lenslite and Reflector provide economical illumination, since you can space such units up to two times the mounting heights, and install in corridors where the width may be as much as 1¼ times the mounting height.



Optical system consists of double-function Corning No. 543021 *Tempered* Corridor Lenslite and C-201 Specular Alzak Reflector.

Why not put this new Lenslite to work in your next job? Get all the facts by sending for Bulletin L-120-M. Write to Lighting Sales Department, Corning Glass Works, 61 Crystal Street, Corning, N. Y.

CORNING GLASS WORKS

CORNING MEANS RESEARCH IN GLASS

(*Lighting News continued from page* 12A)

Round-up of Milwaukee Section Activities

What with lighting courses, extension meetings, study clubs and, of course, regular monthly Section meetings, the Milwaukee Section of IES has had recourse to a monthly newsletter to keep its members informed on all that is going on. This newsletter features a calendar of coming events, profiles of prominent Section members, news of local changes in position, listing of new Section members, and information and statistics on the Section's relation to the national IES picture.

One of the activities recently engaged in was the meeting of the Green Bay Study Club, sponsored by the Section last November. Attendance at the dinner was 85 and at the ensuing meeting was 115. Chairman of the session was John W. Peterson of Green Bay, and guest speakers were Eric H. Church and William Kuhnke.

Another recent activity was the Lighting Fundamentals Course, reported on in December IE, in which 63 students completed the series of eight classes. Those participating included contractors, union members, architects and engineers.

Plans for the future include an extension meeting in Appleton, Wis., sometime in April, for a tour of a paper mill in the Fox River Valley. Topic for the meeting following the tour will be Industrial Lighting.

MASTER of Ceremonies, I. L. Illing, congratulates the "graduating" class at last meeting of the Milwaukee Section's course on Fundamentals of Lighting.

EEI Sponsors Student Architect Competition

A design competition for architectural students is being sponsored by the Edison Electric Institute, with particular emphasis placed on the lighting, in addition to provision for electrical appliances. The house can be designed in any style and should be suitable to climatic conditions in one of four sections of the United States: northeast, northwest, southeast or southwest.

A first prize of $2000 will be awarded for each area and 16 prizes of $400, for honorable mention. In addition 25 per cent of the awarded prize will be given to the school of architecture of the winning student. Deadline for entries is March 2, 1958.

EEI reports that 45 schools of architecture have indicated their students wish to participate.

British IES Holds Golden Jubilee Dinner

On Monday, February 9, members of the British IES held a commemoration dinner at the Criterion Restaurant, Piccadilly Circus, in London. The occasion: their Fiftieth Anniversary.

A message of congratulation from American IES President, George J. Taylor, will be published in the transactions of the British organization.

USSR Industrial Lighting Code Made Available in Translation

English translations of a newly published Russian Industrial Lighting Code together with a paper describing the experimental work which led to the development of the code are being made available by the Permagon Institute of London and New York. This material recently appeared in the Russian magazine, *Svetotechnika*.

The translations were done under the Permagon Institute's cooperative cost-sharing scheme, under which the cost of translation and reproduction is divided equally among subscribers who order a copy within three months of the date of issue. Invoices are sent out at the end of the three-month period.

(*Continued on page* 16A)

INSTRUCTORS in the Milwaukee Lighting Fundamentals course were, l. to r.: front row, R. J. Present; R. R. Cheney, W. C. Kuhnke, I. L. Illing, W. A. Heth, W. L. Lowell; back row, C. N. Laupp, E. H. Schaefer, G. E. Dolan, E. H. Grieb, E. Schnoll, M. H. Bruesewitz. Missing from photo: T. B. Dustin, S. Gellman, F. W. Williamson and W. B. Kennedy.

(Continued from page 15A)

Orders received thus far insure that the final cost per subscriber will not exceed $30.00, with a maximum of two copies available for one share of the cost. The Institute anticipates that the final cost may well be below this figure, as orders are still being received.

Further information may be obtained from David G. Fry, Business Manager, Permagon Institute, 4 Fitzroy Square, London, W.1, England.

Arrowhead Chapter — Now Officially No. 84

With presentation, on December 2, of gavel and charter to the Arrowhead Chapter, San Bernardino, Calif., the number of IES Sections and Chapters became 84. Members and guests from all over the state, including the "parent" Southern California Section, San Diego Chapter, Yosemite Chapter and the Golden Gate Section.

The charter was presented to Chairman Gordon Burgess by Regional Vice-President Jim Barnes. Handing over the gavel was done by Irwin McMath, Chairman of the Yosemite Chapter, until then the "infant" of the Society. William P. "Teddy" Bear presented a talk on the organizational aspects of IES and what its benefits can mean to its members and the public in general.

Following the business portion of the meeting, J. S. Hamel, consulting engineer, presented slides and a talk on "Highlights of the Illumination at the Brussels World's Fair."

From the desk of the President . . .

In a Society such as ours it would be difficult to pinpoint any specific phase of its operation as most important. However, being a technical society, we look to our technical activities for a constant source of information to be disseminated in various ways.

In my talk as Vice-President, at Toronto last August, I stated that we had 25 main Technical Committees with 76 Subcommittees. There are 696 members serving on these committees. Considering such things as committee meetings, preparation of reports, presentation of talks, travel time, etc., it is likely that some 20,000 man-hours are devoted to our technical activity. On this basis, an excess of $100,000 is "donated" by conscientious members to our Society. This donation is a behind-the-scene operation with very little "public" recognition or honor. But as in a theatrical production, we do boast of "star" performers and a supporting "cast" whose names become prominent in IES circles as well as in the electrical industry at large.

Our Technical Committees are primarily responsible for the production of technical reports, which find various forms of printed publication, to reach our members and all those who may use or apply illumination for one reason or another. Such printed material includes lighting recommendations for industry, roadways and airplane runways, sports, residences and display of buildings and memorial objects. Some of our reports are prepared in cooperation with the American Standards Association and thus set "standards" of real importance to a great American enterprise. The true value of our recommended practices cannot be estimated, but many thousands of specifiers of lighting, in whatever capacity, reach millions of people with the work from our technical reports.

The studies of our Technical Committees include the review of scientific developments and researching in the field of lighting and seeing. Many of these could be mentioned, but those most notably before us are from Dr. Blackwell on specific quantity (footcandles) required for seeing tasks and Professor Finch on the detrimental effect of reflected glare on vision. These researches set many committees to working to provide published material for the use of our members and eventually to the "using" public. This information becomes of value in the preparation and presentation of articles and talks, both in a technical and in a popular vein.

These are but a few things of which we are proud in the function of our Technical Committees for performing their obligations and duties to our Society. May I say that as President I am still seeking members who are interested in serving on Technical Committees. If you have such an interest, would you so indicate by writing to me at IES Headquarters. We will send you a simple questionnaire to fill out and will try to place you on a committee suitable to your best interest.

GEORGE J. TAYLOR
IES President, 1958-1959

CHARTER presentation is made by Jim Barnes, South Pacific Coast Regional Vice-President (right) to Arrowhead Chapter Chairman Gordon Burgess, as Board of Managers members Ken Matsuoka, John Gorham and C. G. Dahlgren look on approvingly.

ABOUT PEOPLE

George J. Taylor, IES President, has been named Vice-President and Director of Research for the newly created Research Department of Day-Brite Lighting, Inc., St. Louis, Mo. Mr. Taylor, who assumed this new position in addition to his duties as Vice-President in charge of Eastern Operations for the company, will continue to have his office in New York City. **Charles L. Amick,** who has been with Day-Brite since 1955, most recently as Acting Vice-President, Sales Department, will serve as Executive Director of the Research Department. Mr. Amick came to Day-Brite from the General Electric Co., Nela Park. Also appointed in connection with the

(Continued on page 22A)

. . . DESIRE TO PRODUCE QUALITY COMES FROM THE HEART

Producing high-quality lighting equipment begins in the HEART! Here lies the deep, honest DESIRE to create, to design, to engineer, to build better fixtures and better lighting control devices.

We at Guth are obsessed with that DESIRE!

Our greatest satisfaction is to produce good, honest-quality luminaires that will please the user for years to come —to see our dream ideas become reality through dedicated "all out" efforts in which we've given freely of our energy, time and brains. And then to ship and ship on time—that tops it off!

It all comes from our HEART!

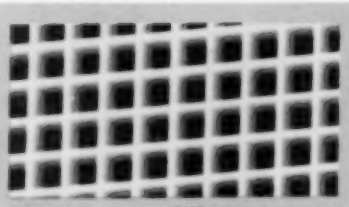
Guth

LIGHTING SINCE 1902

OPEN HERE... SEE HOW GUTH DESIRE WORKS FOR YOU!

DESIRE TO CREATE

Ideas are the "life-blood" of our business. We never stop thinking, experimenting—striving to create new and better lighting devices. A few of the many Guth-created "stars":



GRATELITE Louver Diffuser®

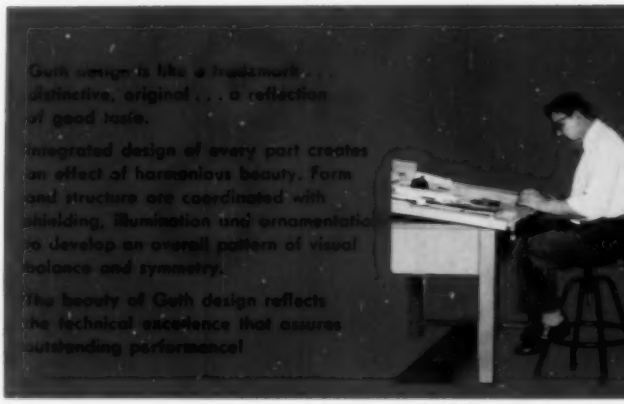
. . . combines openness of a louver with diffusion power of glass . . . high intensity lighting with extremely low brightness. 3/8" cubes provide 45° x 45° shielding. As complete ceilings, or in fixtures, they create great beauty.

SLIMFIN†

. . . the latest result of Guth's desire t
create! A brand new slim fixture wi
"fin-wings" for ceiling-glow and exci
ing decor.

DESIRE TO DESIGN

In every Guth Fixture, you see the result of Guth's desire to bring forward-looking design to lighting.



Guth design is like a trademark . . .
distinctive, original . . . a reflection
of good taste.

Integrated design of every part creates
an effect of harmonious beauty. Form
and structure are coordinated with
shielding, illumination and ornamentation
to develop an overall pattern of visual
balance and symmetry.

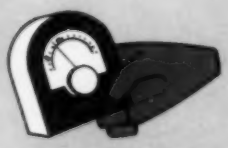
The beauty of Guth design reflects
the technical excellence that assures
outstanding performance!

DESIRE TO ENGINEER

The result of Guth's dedication to creative engineering is seen in every detail of Guth lighting equipment.

SPECIFIC LIGHTING JOBS

Light beam projection boards are utilized to accurately engineer reflectors for specific lighting requirements. Strips of bent aluminum establish exactly where beams will be reflected. On the basis of these reflection factors, full size models are formed.

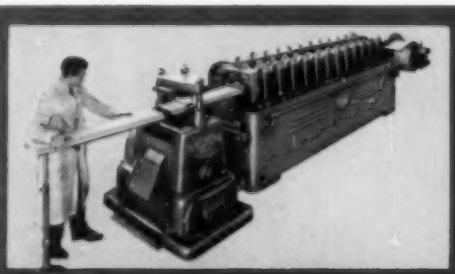


LIGHT OUTPUT, BRIGHTNESS AND TEMPERATURE CONTRO

Every fixture and shield is test
to make sure brightness leve
and light output meet Gu
Quality standards for eye co
fort and efficiency. Heat tests a
sure long ballast life and safet

DESIRE TO BUILD

Guth is always looking for better production methods . . . regularly and constantly investing in advanced machinery and material handling devices . . . seeking to deliver higher quality at lower cost.



Automatic roll
parts at the rate of 14 miles in 24 hours. Then parts
are cut to accurate lengths (within 1/64th")
automatically! They always fit!

Spinning—just one of the
skilled crafts at Guth. Crafts
form thousands of reflect
shapes for incandescent lu
aires and special fixtures.

BE SURE TO SEE THE BACK PAGE

Guth
lighting

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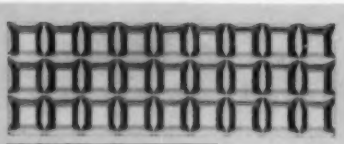
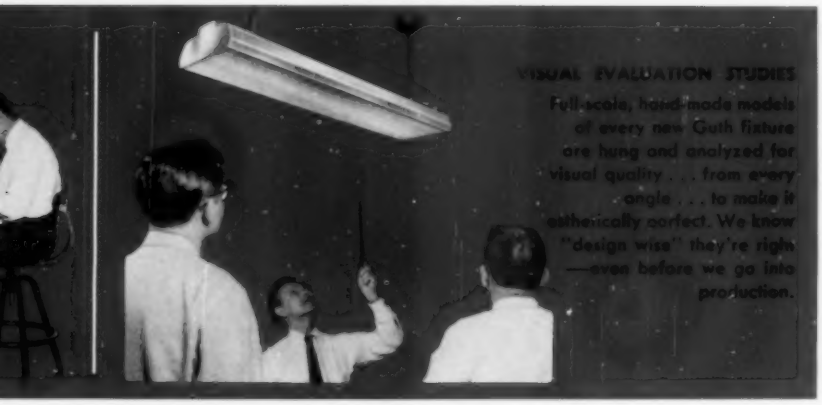
BRASCOLITE® INCANDESCENTS
. . . a complete new line—rounds, squares, recessed, pendants—all years ahead in beauty and performance—with crisp, clean designs, high quality materials and efficient, permanent ALZAK reflectors.



PRISMOID GRATELITE**
reversible louver-lens
. . . creates a panorama of ever-changing light patterns when viewed from different angles. It's reversible! Apex down, it sparkles, twinkles—and delivers 88.6% efficiency. Apex up, it delivers 86.1% efficiency with eye-easy brightness comfort. Available in many Guth fixtures.

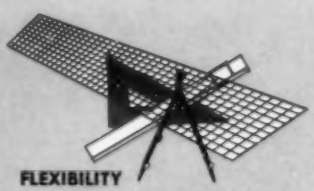
WYTELINER® INDUSTRIALS
The very latest in industrial luminaires. Completely re-tooled for new Power Groove, HO, VHO and SHO lamps . . . 13° and 27° shielding . . . 10% and 25% uplight. Available with louvered and diffusing bottoms—in Baked-on White and Alzak finishes. Also, all new RLM Porcelain enamel line.

*®U. S. Pat. 2,745,001 Can. Pat. 1957, 538,245
**®U. S. and Can. Pats. Pend.
†U. S. and Can. Pats. Pend.



VISUAL EVALUATION STUDIES
Full-scale, hand-made models of every new Guth fixture are hung and analyzed for visual quality . . . from every angle . . . to make it esthetically perfect. We know "design wise" they're right—even before we go into production.

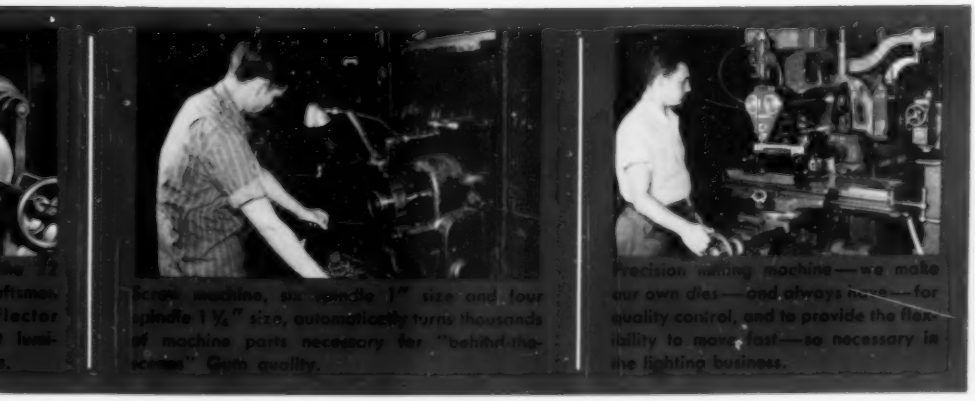
NESS
NTROL
s tested
s levels
Guth-
ve com-
tests as-
safety.



FLEXIBILITY
Guth Lite-Blox Troffers are engineered to fit 83 ceiling suspension systems! Many fixtures are engineered to accept a wide variety of bottoms . . . and for other variations which make them adaptable to specific jobs.

UNSEEN QUALITY
This intricate part is completely hidden—by sides and end plates—yet here is an engineering triumph. Weeks to design . . . months for die making . . . this precision engineered "heart" creates added strength, durability and long life in the new Guthlite, Jr.

STRENGTH
8-foot Guth fixtures will hold a heavy man without sagging. Constructed of heavy gauge steel and aluminum—then ribbed and reinforced for extra strength . . . they're sturdy and solid to "stand up" on the job.

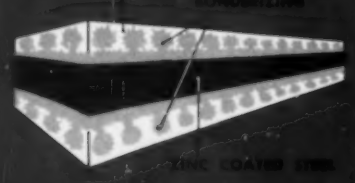


Screw machine, six spindle 1" size and four spindle 1¼" size, automatically turns thousands of machine parts necessary for "behind-the-scenes" Guth quality.

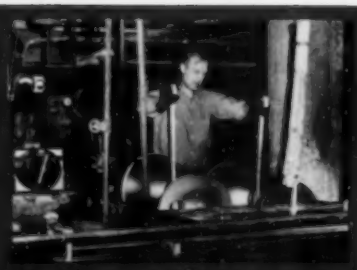
Precision [illegible] machine—we make our own dies—and always [illegible]—for quality control, and to provide the flexibility to move fast—so necessary in the lighting business.

DESIRE FOR QUALITY FINISHES

Guth uses the finest materials available—at no extra cost to the user!



A 100% Pencoat coated is baked-on premium, zinc coated and Bonderized steel to assure a glistening, snow white finish that adheres tenaciously to the heavy gauge steel—minimizes rust and corrosion in any climate, guarantees top reflector efficiency.



Lifetime ALZAK finish for aluminum reflectors. Two patented, 13-operation Alzak process, that locks in reflector brilliance permanently—operated in accordance with Alcoa standards for maximum efficiency and permanency.

LIGHT ENGINEERING DATA

Guth goes all out to provide data you need to predetermine the lighting job . . . in convenient, easy-to-read form.

FIELD MEN WITH LIGHTING KNOW-HOW

They know the lighting business inside out. They're factory trained specialists—fully qualified to assist you.

DESIRE TO SERVE

The folks at Guth are dedicated to the idea that HIGH QUALITY SERVICE is just as important as HIGH QUALITY lighting equipment!

CAREFUL ORDER HANDLING

When your order arrives—ACTION STARTS! It's processed immediately—and followed up all along the line to make sure it's right.

PROMPTNESS IN CORRESPONDENCE

Need info? A letter or wire brings it quick. No piles of unanswered letters on the desks at Guth!

A PROMISE IS OUR BOND

If we cannot ship your order TODAY, we'll tell you so—in advance. Once we give you our promise, you can count on it.

CAREFUL PACKAGING

With heavy-duty cartons engineered for each fixture. They fit! No breakage in transit. Every part you need is there. You save time and labor.

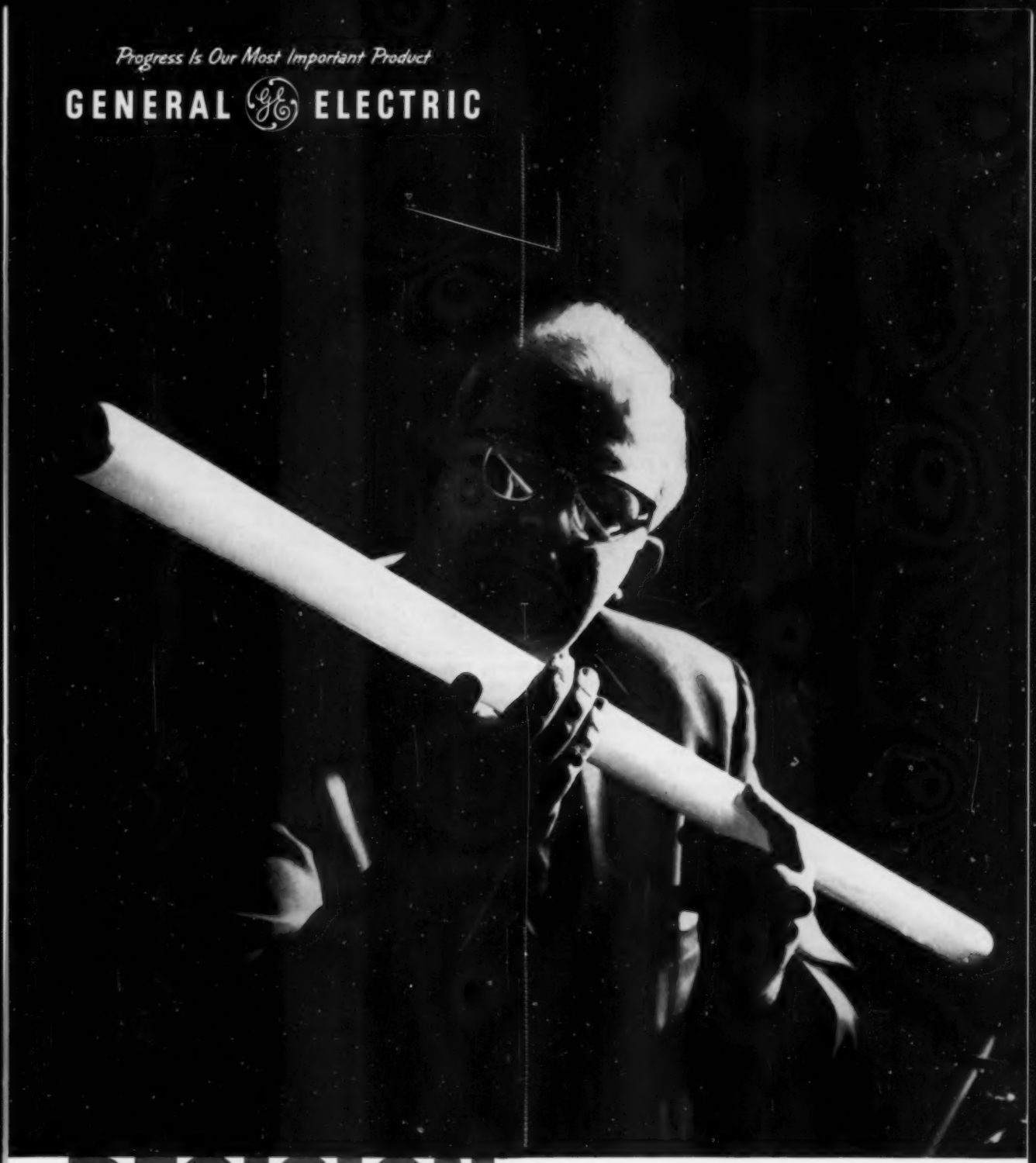
THE EDWIN F. Guth COMPANY • ST. LOUIS 3, MO.

QUALITY LIGHTING FIXTURES SINCE 1902

Printed in U.S.A.

Progress Is Our Most Important Product

GENERAL ELECTRIC



DECISION

"Alone . . . just me and my question . . . which lamps to buy. All look about alike . . . but I keep remembering what past experience has proved to us about General Electric Lamps. That 999 out of 1,000 are sure-starters . . . and 99 out of 100 will still be burning in 1961. And happy thought! We pay less for a case of G-E Fluorescent Lamps today than we did in 1950!"

DECISION: "Why gamble on performance when I can get G-E Lamps at little or no premium in the purchase price."

General Electric Co., Large Lamp Dept. C-905, Nela Park, Cleveland 12, O.

SECTION and Chapter officers in attendance at the Southwestern Regional Organizational meeting (see story, January IE, p. 9A) were: Front row, left to right, Harold W. Powell, Panhandle; George H. Simpson, San Jacinto; John B. Deck, Jr., Regional V-P; M. H. Perkins, Ark-La-Tex; E. L. Cole, North Texas. Back row, W. T. Kimery, North Texas; Ken Hightower, Ark-La-Tex; Don Copeland, San Jacinto and Russell Trainick, South Plains.

(*Continued from page* 16A)

formation of the new department are: **Murray L. Quin** as Senior Director; **Richard D. Bradley** as Technical Director and **Milton Buzan** as Manager of Advanced Engineering.

Robert E. Lewis has been elected as President of Sylvania Electric Products, Inc., according to a recent announcement by the company's Board of Directors. Mr. Lewis, who was formerly a senior Vice-President of the firm succeeds Don G. Mitchell, who will continue as Chairman of the Board. This follows the proposed merger of Sylvania into General Telephone Co. It is contemplated that Mr. Mitchell will become President of the combined company, to be known as General Telephone and Electronics Corp.

Westinghouse Lamp Division has announced the appointment of **Richard F. Townsend** as director of commercial engineering activities for large incandescent lamps. Mr. Townsend will make his headquarters in Bloomfield, N. J.

John C. Virden, Jr., president of John C. Virden Co., Cleveland, has been elected president of the American Home Lighting Institute for 1959. **Stanley A. Framburg**, H. A. Framburg & Co., and **Max Shemer**, Esty Manufacturing Co., both of Chicago, were elected as vice-presidents; and **Ted Cox** was re-elected managing director. New members of the nine-man Board of Governors are: **A. M. Rosenblatt**, Globe Lighting Products; **Jack Goldberg**, Jay Lighting Mfg. Co.; **Eugene Berman**, Leader Lamp Mfg. Co.; **E. H. R. Blitzer**, Lightolier, Inc.; **William Epling**, Prescolite Mfg. Corp. and **Maurice C. Rosen**, Progress Mfg. Co. Elections took place at the Institute's annual membership meeting in New York City in late December.

Crouse-Hinds Co., Syracuse, N. Y. has named two new divisional managers to fill the vacancies left by the retirement of the two former managers. **William R. Major, Jr.** has succeeded **Harry D. Rei** as head of the Southeast Division; **George B. Jamison** has taken over in the Gulf Division, replacing **G. G. Griffin.** Both new division managers have been with Crouse-Hinds for several years, in various capacities, Mr. Major since 1946 and Mr. Jamison since 1944.

Thomas Fuller has been elected vice-president of Thomas Industries, Inc., Louisville, Ky., according to a recent announcement. Mr. Fuller will continue to serve as general sales manager for the company, a position he has held for three years.

Edwin D. Tillson, Evanston, Ill., continues in his practice as an independent consulting engineer, with Appelton Electric Co. as his newest client. An item in the December issue of IE erroneously indicated that Mr. Tillson had given up his private practice and was working solely for Appelton.

A. M. Swassey, General Electric Co., Hendersonville, N. C. has been elected chairman of the Aviation Ground Lighting Section of NEMA for 1959, according to a recent announcement. Also elected were **E. B. Karns,** Westinghouse Electric Corp., as vice-chairman and **J. S. Haney,** Crouse-Hinds Co., as chairman of the general engineering committee.

Inland Glass Division of the Club Aluminum Products Co., La Grange Park, Ill. has announced the promotion of **Charles E. Anderson** to sales manager for lighting and industrial glass products. Mr. Anderson moves to this newly-created post from the position of assistant sales manager for lighting, industrial glass and giftware.

Quadrangle Manufacturing Co., Chicago, Ill., has announced the signing of two new sales representatives: **Roy L. Clinton,** Canonsburg, Pa., for western Pennsylvania and northern West Virginia, and **R. E. Madigan,** Brookfield, Wis., for Wisconsin and the upper peninsula of Michigan.

Ronald Stone has joined the executive staff of House-O-Lite Corp., Chicago, Ill. as assistant to Executive Vice-President **E. P. Winkel,** it has been announced.

Hexcel Products, Inc., Berkeley, Calif., has named A. E. Lilly Co., **William W. Collier,** president, as their northern California sales representatives. Announcement was made by **Roscoe T. Hughes,** vice-president and general sales manager for Hexcel.

William Thomas Cavanaugh has been appointed Executive Director — Secretary-Treasurer of the National Office Management Association, with offices in Willow Grove, Pa., it has been announced by **F. A. Schultz,** International President of the Association. Mr. Cavanaugh was recently Executive Secretary of the Manpower Commission of the Engineers Joint Council, New York.

Ekco Products Co., Chicago, Ill., has announced the election of **Robert C. Sabini** and **Donald S. Burns** as vice-presidents of the company. Both men have been with Ekco or its subsidiaries for several years. Mr. Sabini is president of Worley & Co., Pico Rivera, Calif. subsidiary of Ekco. Prior to that he was assistant to the president of Ekco. Mr. Burns is president of McClintock Manufacturing Co. and Lighting Dynamics, subsidiaries of Ekco in Whittier, Calif.

Deaths

James R. Barry, San Diego Section.
Marvin Westrick, Michigan Section.

(*Lighting News continued on page* 25A)

When price is not the main consideration

It Costs So Little More To Have Good Lighting

DOWN LIGHT—TOO CONCENTRATED

Low-brightness on the *object* you are looking at
No brightness on the *vertical* surfaces

KIRLIN—WIDE SPREAD—GLARE-FREE

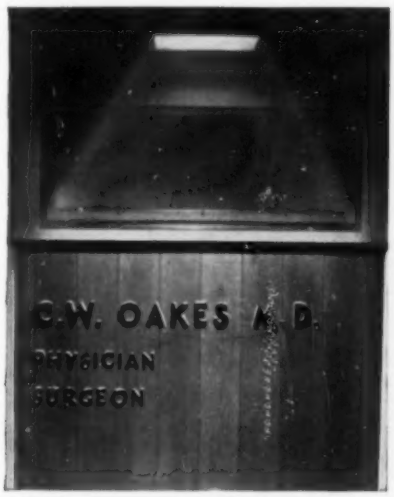
All objects to be seen are well lighted
Wide distribution lights the vertical surfaces

No "Hot Spot" with Kirlin Lenses

Down lights are intended for spot lighting—not for area lighting
(*shown are three 150 W. units*)

Bill—
they're right—
lets use Kirlins
J.C.

Kirlin
SYSTEM
BUILT-IN
Lighting



Kirlin louver glass directs the light at an angle—uniformly
(*shown is one 150 W. unit*)

SALES ENGINEERS IN PRINCIPAL CITIES

The KIRLIN CO. 3435 E. JEFFERSON AVE. DETROIT 7, MICHIGAN

- **Available in many types and sizes**
- **In stock at leading wholesalers**
- **Underwriters Laboratory and I.B.E.W. labels**

problem

High-foot-candle levels from recessed fixtures were required for Pereira & Luckman's contemporary design of the new IBM Western Headquarters Building.

solution

The ARGUS LUMINAIRE was designed by Lighting Dynamics. Now in production, it is the first recessed troffer using high output and very high output lamps supplying high-footcandle levels to critical seeing areas in drafting, engineering rooms, laboratories, banks, and offices. ARGUS' clean contemporary lines produce EXCITING ARCHITECTURAL EFFECTS with long parallel strips of unbroken light. This new series comes in a WIDE VARIETY OF WIDTHS AND LENGTHS that completely integrate with ceiling materials. Easy to install. As with all Lighting Dynamic luminaires, the Argus features durable, Bonderized and electrostatic, high-reflectance finishes. FOR MORE COMPLETE INFORMATION fill out the coupon below and mail to Lighting Dynamics, 802 West Whittier Boulevard, Whittier, California; or to Lighting Dynamics, 8700 Ambassador Row, Dallas, Texas.

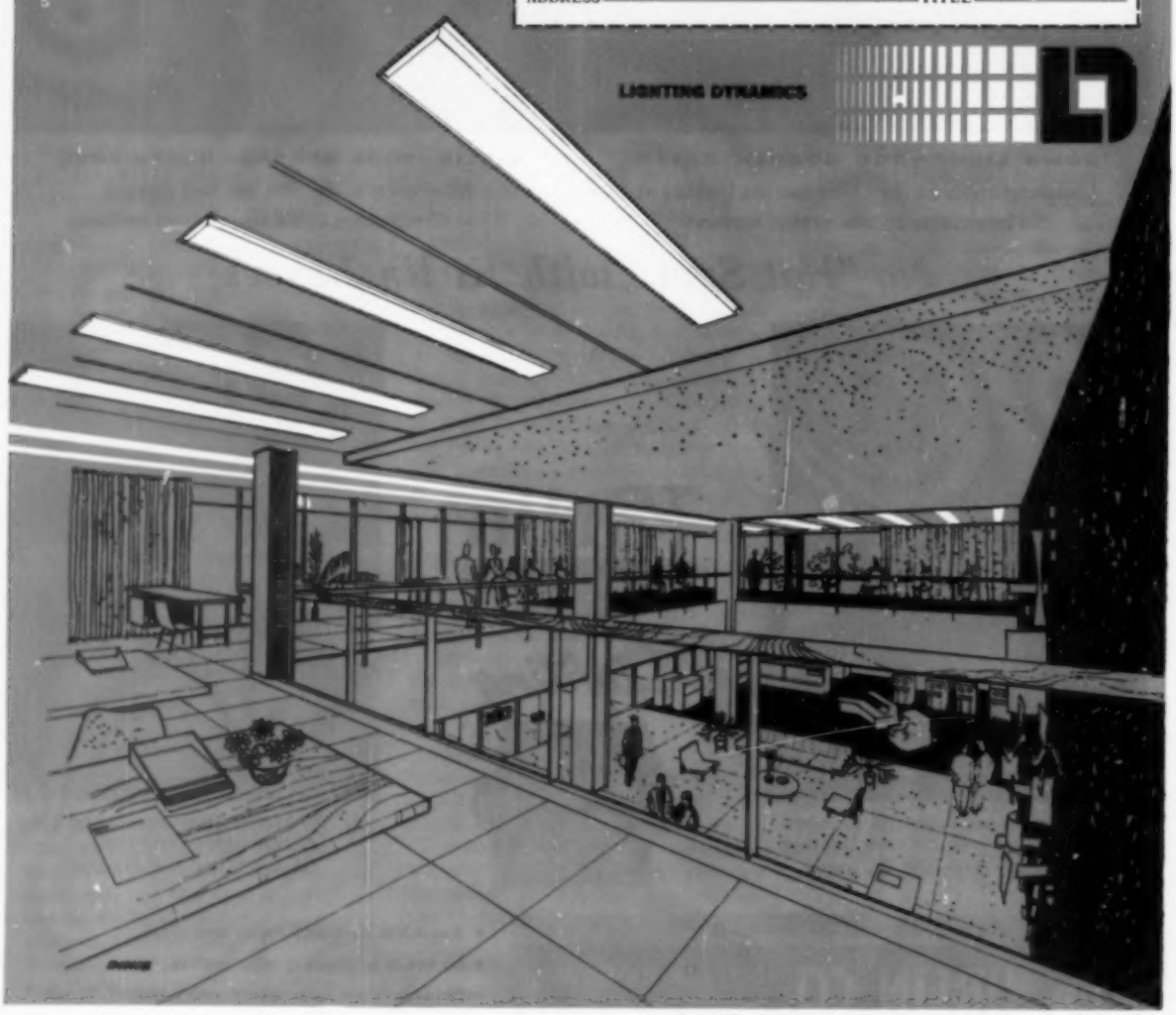
_____ *Send more information on* ARGUS.

_____ *Send your new catalog.*

NAME _____ PHONE _____

ADDRESS _____ TITLE _____

LIGHTING DYNAMICS



ARGUS as it will be used in the IBM Western Headquarters Building designed by Pereira & Luckman.

SHEFFIELD ANNOUNCES FIRST

1959 Regional Conferences — I.E.S.

Region	Place	Date
East Central	Lord Baltimore Hotel Baltimore, Md.	April 9-10
South Central and Southeastern	Grove Park Inn Asheville, N. C.	April 23-24
Southwestern	Shamrock-Hilton Hotel Houston, Texas	May 4-5
Midwestern	Pere Marquette Hotel Peoria, Ill.	May 6-8
Inter-Mountain	Continental Hotel Denver, Colo.	May 11-12
Pacific Northwest	Banff Springs Hotel Banff, Alta.	May 26-30
Northeastern	Curtis Hotel Lenox, Mass.	June 4-5
Canadian	Chateau Laurier Ottawa, Ont.	June 11-12
Great Lakes	Lafayette Hotel Buffalo, N. Y.	June 22-23

(*Lighting News continued from page 22A*)

BOOKS AND PAMPHLETS

Maintenance Hints, published by Westinghouse Electric Corp., P. O. Box 2099, Pittsburgh, Pa. 650 pp., $2.00.

This revised 24-chapter handbook is designed as a quick and complete guide to modern maintenance practices on all types of electrical equipment. It is divided into two sections; the first 17 chapters dealing with specific apparatus maintenance, and the last seven covering general maintenance of materials used in apparatus, such as insulation. Copies may be ordered from Westinghouse at the above address.

A New Concept in Store Lighting Promotion, published by Electrical Information Publications, Inc., 2132 Fordem Ave., Madison 1, Wis.

The four 5½- x 7-inch colored postcards contained in this folder feature reproductions of various store lighting installations—store front, show windows, general retail and impulse lighting. The series is intended for use by utilities in promoting better lighting. A message on the back of each card reminds the recipient of the advantages of good lighting for increasing sales. Samples of the cards are available from R. H. Schneider, Sales Promotion Manager, at the above address.

American Standards D10.1 - 1958, Adjustable Face Traffic Control Signal Head Standards; D11.1 - 1958, Pre-Timed Fixed Cycle, Traffic Signal Controllers; D13.1 - 1958, Traffic Actuated Traffic Signal Controllers and Detectors, published by American Standards Association, 70 East 45th St., New York 17, N. Y.

Revisions of three important Standards by which traffic engineers throughout the United States buy signal equipment have just been approved. These publications, sponsored by the Institute of Traffic Engineers are among the most important and widely-used American Safety Standards. Copies available from ASA.

American Standards C82.1 - 1958, Specifications for Fluorescent Lamp Ballasts and **C82.2 - 1958, Methods of Measurement of Fluorescent Lamp Ballasts,** published by American Standards Association, 70 East 45th St., New York, N. Y., $1.00 each.

American Standard C82.1, a revision of an earlier 1958 standard, now includes specifications for ballasts used for trigger-start operation of 14-, 15-, and 20-watt pre-heat lamps. It also covers ballasts having rated open-circuit voltages of 2000 volts or less. C82.2, first published as a Proposed Standard in 1950, outlines the procedures to be followed and precautions to be observed in testing ballasts for hot-cathode, continuously-heated cathode and cold-cathode fluorescent lamps. Both standards are intended for use in conjunction with *Specifications for Fluorescent Lamp Reference Ballasts,* C82.3-1957, and the C78 series of *Dimensional and Electrical Characteristics of Electric Discharge Lamps.*

MEMO to hotel manager: see July 1958 IE.

"Twenty-five bucks a day,- and lousy lighting!"

NEW MEMBERS

At the meeting of the I.E.S. Council Executive Committee on January 8, the following were elected to membership. Names marked * are transfers from Associate Member Grade. Names marked ** are transfers from Student Member Grade.

ALABAMA SECTION

Associate Member:

Barber, R. L., Alabama Power Co., Atmore, Ala.

ARIZONA SECTION

Associate Members:

Bennan, J. B., Jefferson Electric Co., 6130 Calle Del Sud, Scottsdale, Ariz.

Norton, A. F., W. C. Osborn, P. O. Box 6506, Phoenix, Ariz.

ARKANSAS CHAPTER

Associate Member:

Greene, J. E., Central Electric Supply Co., Pine Bluff, Ark.

ARK-LA-TEX CHAPTER

Associate Members:

Cefalu, A. C., Westinghouse Electric Supply Co., Shreveport, La.

Holland, J. C., Federal Pacific Electric Co., Shreveport, La.

(*Continued on page 28A*)

SHEFFIELD PLASTICS, INC.
FROST-WHITE

SHEFFIELD ANNOUNCES FIRST GUARANTEED LIGHT STABLE* STYRENE PLASTIC DIFFUSERS

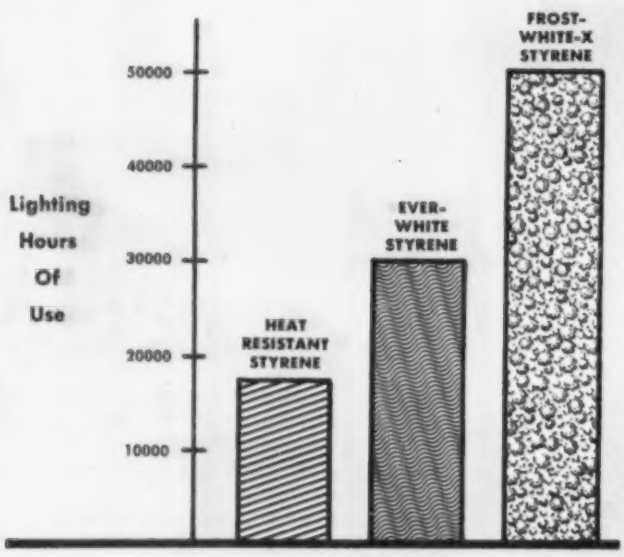
Frost-White-X† diffusers now guaranteed against discoloration for 50,000 lighting hours

You can now obtain styrene shields and pans for fluorescent fixtures that not only have outstanding resistance to breakage and extreme flexibility, but are backed by a written guarantee against excessive discoloration for 50,000 lighting hours!!

The result of a 2-year development program, Sheffield's Frost-White-X styrene is the first to be so guaranteed. Exhaustive laboratory tests have established its light stability and made it possible for Sheffield to issue this guarantee.

In addition, Frost-White-X diffusers have a non-reflecting surface finish, will not become brittle with long use and can be colored to match your requirements

† TRADE MARK



Light stability of FROST-WHITE-X diffusers is more than twice that of heat resistant styrene diffusers.

Fixture Designers and Manufacturers

Frost--White-X diffusers permit you to:

1. Guarantee their light stability.
2. Use economical styrene diffusers instead of acrylic or glass.
3. Eliminate practically all breakage in shipping and handling.
4. Cut material costs by reducing diffuser cross-sections.
5. Simplify fixture design and assembly.

Architects

By specifying Frost-White-X diffusers or pans you can:

1. Avoid degradation and put lasting quality and appearance into lighting fixtures.
2. Minimize fixture cost without sacrificing performance.
3. Improve lighting efficiency.
4. Simplify cleaning and maintenance.
5. Increase design possibilities.

See us at Booth 73, the 2nd National Lighting Exposition, March 1-4, New York City.

SHEFFIELD PLASTICS, INC.
FROST-WHITE-X
Light Stability
GUARANTEE
Plastic shields, diffusers or pans made with Sheffield Frost-White-X polystyrene are guaranteed to withstand 50,000 lighting hours in fluorescent fixtures without discoloration due to ultra violet light in excess of 20 points*, as measured by the test procedure outlined by the IES-SPI-NEMA Subcommittee of the Light Control and Equipment Design Committee of the Illuminating Engineering Society in its report, dated February, 1958, on "Recommended Light Characteristics of Polystyrene Used in Illumination."
This guarantee shall apply to all Frost-White-X material used under the following conditions:
1. The "X" (exposed) side of the plastic shall be placed adjacent to and at least 1" away from the fluorescent tubes.
2. The fluorescent tubes used shall not exceed 40-watts in standard white, standard warm white, standard cool white, daylight or equivalent types.
3. The average temperature of the plastic in use shall not exceed 110 F.
Any shields or pans made with FROST-WHITE-X polystyrene which fail to conform to the terms of this guarantee, will be replaced free of charge, under conditions identical to the original contract, upon submission to Sheffield Plastics of proof – including samples of the faulty plastic – that the original shields or pans failed to meet the conditions of this guarantee.
*50,000 lighting hours, for reference purposes, is equivalent to approximately 11 years of light-use use based on exposure for 10 hours per day, 6 days per week.
Yellowness Factor = 100 − (T420 − T420) − (T680 − T480) / T560
where
T420 = % transmission of same thickness of unexposed material at 420 mu.
T420 = % transmission of specimen at 420 mu.
T680 = % transmission of same thickness of unexposed material at 680 mu.
T680 = % transmission of specimen at 680 mu.
T560 = % transmission of same thickness of unexposed material at 560 mu.
Specimens examined with spectrophotometer, for degree of yellowness in accordance with Luminous Reflectance and Color of Materials (ASTM D791) and the following equation:
LIGHT STABILITY GUARANTEE
50,000 LIGHTING HOURS
FROST-WHITE-X
polystyrene
SHEFFIELD PLASTICS, INC.
SHEFFIELD, MASS.
SHEFFIELD PLASTICS, INC.
SHEFFIELD, MASS.

★ The Sheffield Guarantee of Light Stability — given to every user of Frost-White-X diffusers and sheet material — *guarantees replacement* of any Frost-White-X fluorescent fixture component which exhibits more than 20 points of yellowness** after 50,000 lighting hours.

** As defined by the Light Control and Equipment Design Committee, Illuminating Engineering Society.

Break-resistant FROST-WHITE-X shield easily withstands bend around circline lamp.

WRITE FOR COMPLETE DETAILS

Sheffield Plastics Inc.
Section 91-B
Sheffield, Mass.

..... Send details on your Frost-White-X guarantee of light stability.
..... Send technical data on Frost-White-X diffusers.
..... Have your representative call.

Name ..... Position .....

Company .....

Street .....

City ..... Zone ..... State .....

FIRST IN PLASTICS FOR LIGHTING

SHEFFIELD PLASTICS INC.

SHEFFIELD, MASS.

COUNCIL EXECUTIVE Committee hears state-of-operation reports from senior staff. Reporting on over-all Society affairs at the Committee's January 8 meeting is A. D. Hinckley, Managing Director (standing). Reports were also made by C. E. Ellis, Advertising Manager and Ruby Redford, Editor, covering future plans, and comprehensive details (with charts) of the 1958 operation. Left to right in the picture are G. F. Dean, Treasurer; Mr. Ellis, Mr. Hinckley; G. J. Taylor, IES President; C. L. Crouch, Technical Director; and R. G. Slauer, Second Vice-President. Also present (behind the camera), Miss Redford.

(*Continued from page 25A*)

Smith, W. R., Jr., Electric Contracting Co., Shreveport, La.

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Associate Member:

Fultz, D. S., Canadian Westinghouse Supply Co., Halifax, N. S.

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Clemens, James, Sandee Manufacturing Co., Chicago, Ill.
Grassly, C. H., Sylvania Electric Products, Inc., Melrose Park, Ill.
Johnson, D. R., American National Bank Bldg., Rockford, Ill.
McReynolds, J. W., 4956 Kirk St., Skokie, Ill.
Nelson, C. E., Sylvania Electric Products, Inc., Melrose Park, Ill.
Rauch, W. K., Corning Glass Works, Chicago, Ill.
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*Holmes, R. E., General Electric Co., Cleveland, Ohio.

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Phillips, J. D., Nebraska-Iowa Electrical Council, Omaha, Nebr.

EASTERN PENNSYLVANIA SECTION

Associate Members:

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Harnish, C. B., 446 Hostetter Drive, Millersville, Pa.

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King, P. T., Lighting Materials Ltd., Edmonton, Alta.

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Coad, O. E., 1201 Fairview Ave., Winter Park, Fla.
Connelly, G. W., Florida Power & Light Co., Daytona Beach, Fla.
Hampton, D. R., Joseph M. Shifalo Associates, Winter Park, Fla.
Olive, J. E., Palmer Electric Co., Winter Park, Fla.

FOREIGN NON-SECTION

Associate Member:

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GOLDEN GATE SECTION

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Associate Members:

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Grundy, R. D., Pacific Gas & Electric Co., San Francisco, Calif.
Newcomer, W. W., Lok Products Co., San Mateo, Calif.
Sturgeon, J. J. H., Pacific Gas & Electric Co., Concord, Calif.

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Romer, R. F., Romer Electric Co., Indianapolis, Ind.
Turpin, J. B., Sylvania Electric Products Inc., Indianapolis, Ind.

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Repp, C. W., Washington Water Power Co., Spokane, Wash.

IOWA SECTION

Associate Members:

Gardner, F. R., Westinghouse Electric Supply Co., Davenport, Ia.
Maffit, J. E., Iowa Power & Light Co., Des Moines, Ia.

(*Continued on page 46A*)

I.E.S. National Technical Conferences

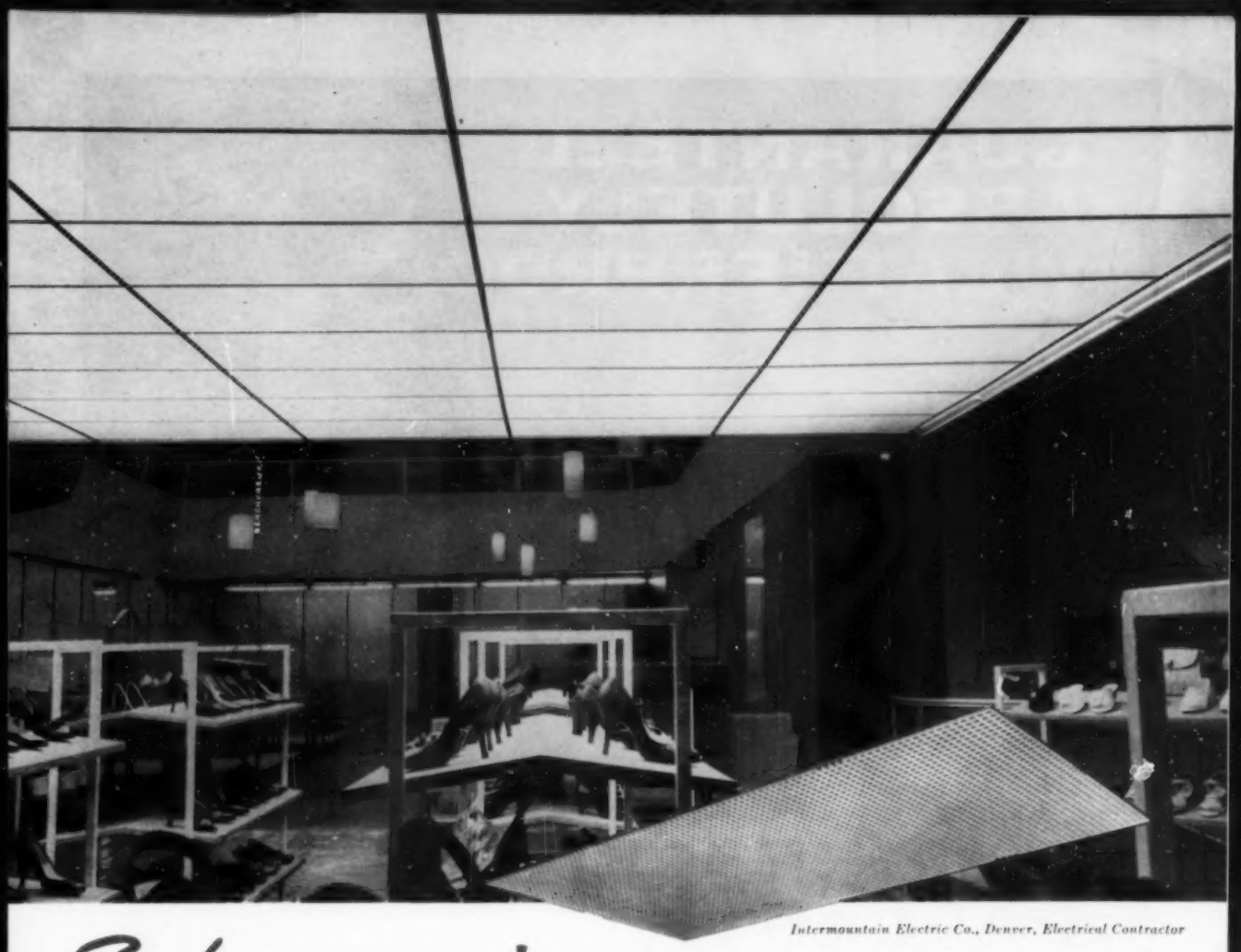
1959 — September 7-11 — Hotels Fairmont and Mark Hopkins, San Francisco, California

1960 — September 11-16 — Penn Sheraton Hotel, Pittsburgh, Pennsylvania

1961 — September 24-29 — Chase Park Plaza Hotel, St. Louis, Missouri

1962 — September 9-14 — Statler-Hilton Hotel, Dallas, Texas

INC.
SHEFFIELD, MASS.



Intermountain Electric Co., Denver, Electrical Contractor

Sinko LOW BRIGHTNESS Louvers ANSWERED THIS LIGHTING PROBLEM

Illuminating Engineer Carl Schranz of the Newman Schranz Lighting Company, in conjunction with Architect Richard L. Crowther, solved the lighting problem in The Fontius Shoe Store in Denver, in which Sinko Gray-Cell Louvers played an important part.

PROBLEM—To install a drop luminous ceiling with a balcony wall on two sides, and the high ceiling with several conventional fixtures, a 300 foot candle level on the merchandise was desired.

SOLUTION—96" T 17 power groove, cool white lamps in fixtures suspended 30 inches above a luminous ceiling of Sinko's Lo-Brite, Gray-Cell, Plastic Louvers, supported in an aluminum inverted tee, grid system.

RESULT—This unusual treatment was the answer to obtaining the three A's of store lighting . . . attracting the customer . . . easy appraisal of merchandise . . . and a relaxing atmosphere.

You, too, can achieve clean-cut, modern appearance, with minimum maintenance with indestructability by specifying Sinko Thin-Cell Louvers for your jobs. These Louvers reduce surface brightness and increase working level efficiency.

Thin-Cell Louvers offer many advantages—write today for literature describing these advantages in detail.

We invite you to visit the Sinko display at the National Lighting Exposition, Spaces 44-45, March 1 thru 4, at the New York City Coliseum.

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Flourtown, Pennsylvania
CHestnut Hill 8-1010

Julius J. Dreyfuss' Sons
124 Peters Street, S.W.
Atlanta 3, Georgia
MUrray 8-6355

Jannel Plastics Sales Co.
9020 Broadway
Cleveland 27, Ohio
VUlcan 3-7161

Julius J. Dreyfuss' Sons
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Julius J. Dreyfuss' Sons
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Lighting Parts, Inc.
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San Francisco 2, California
YUkon 2-5788

Lighting Parts, Inc.
191 East Jefferson Blvd.
Los Angeles 11, California
ADams 3-8111

Eugene Meth & Assoc.
1010 St. Catherine W.
Montreal P.Q., Canada
UNion 1-6218

export sales office:

Reidan Export International
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St. Louis 5, Missouri

Sinko Louvers produced and sold by

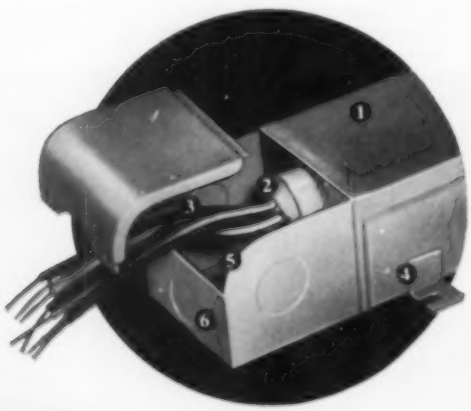
SINKO MANUFACTURING AND TOOL CO.
7310 W. WILSON AVE., CHICAGO 31, ILL.

GUARANTEED ABSOLUTELY WEATHERPROOF

JEFFERSON FLUORESCENT BALLAST

FOR HIGHWAY LIGHTING, AREA LIGHTING, BILLBOARDS, AND PLASTIC SIGNS

The new Nor'easter—first fluorescent ballast that is completely weatherproof—guaranteed against service failure due to weather conditions for 2 years.



1. **WEATHERPROOF, CORROSION-PROOF CASE** Entire case is hot-dip galvanized. After ballast assembly, the seams of the lid are *sealed* to form a completely weather-tight unit.
2. **AQUALIFT SEALED PIPE NIPPLE**—Jefferson's exclusive Aqualift Sealant prevents moisture from entering through the pipe nipple—retains its sealing properties thru extremes of heat and cold.
3. **NEOPRENE LEADS** will withstand exposure to weather and temperature changes without deterioration.
4. **HEAVY GAUGE MOUNTING**—Extra heavy mounting brackets.

EASY INSTALLATION

Mount it in any position—this ballast has no "upside down" or "backwards"

5. **LARGE, EASILY ACCESSIBLE WIRING COMPARTMENT**—open on two sides—conduit lock nuts easily secured.
6. **FOUR KNOCKOUTS**—on either side, bottom, and end of ballast.

Models available for 800, 1400 and 1500 M.A. lamps. Send for complete information—temp. ratings, dimensions, weights, and electrical specifications.

Jefferson WEATHERPROOF BALLASTS

Jefferson Electric Company, Bellwood, Illinois

MARRIED 25 YEARS

MAJOR

Awarded an exclusive ALZAK license from ALCOA over a quarter century ago!

ALZAK

Maintains same brilliant reflective powers even after many years of use!

LIKE

Love and Marriage

...they go together!

NEW MAJOR FACTORY

National Demand for ALZAK* Process Reflectors force MAJOR to Expand Again!

Yes, we've just completed building new and even larger facilities for manufacturing ALZAK PROCESSED aluminum reflectors here at MAJOR! We can now offer you not only *better service*—but also *lower cost*—at the same high standards of quality that have made the name MAJOR famous.

THAT'S why it's always wise to specify MAJOR ALZAK-Processed reflectors on every inside or outside lighting job that comes your way. The MAJOR-ALZAK combination assures you a vastly superior reflector that does not rust, tarnish, chip, or peel—that gives you far more brilliant lighting results.

**A proprietory term of the Aluminum Company of America.*

Write - Call - For Your MAJOR SILVER ANNIVERSARY GIFT!

We'd like to have you celebrate with us—send us your Name, Company Name and Address.

MAJOR EQUIPMENT COMPANY

4603 Fullerton Avenue • Chicago 39, Illinois

SPaulding 2-7600

Revere Outdoor Lighting Report

Revere ELECTRIC MFG. CO.

Lighting a store front

The Problem: To draw attention to a store front and make it look inviting to shoppers by providing high level, uniform lighting for the wall and sidewalk area.

The Answer: Revere 9605 Fluorescent Luminaires were installed to give the high level of illumination desired. Eight-foot units were joined to form a continuous, attractive light source that makes the store look inviting. Each 8-foot unit contains two Very High Output lamps and has two 4-foot doors for fast, easy cleaning and maintenance.

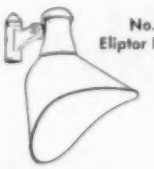
No. 9605
Fluorescent Luminaire

Lighting a race track

The Problem: To illuminate a race track for better visibility, and to provide especially high intensity lighting for dramatic effect at the finish line.

The Answer: Revere Eliptor Floodlights mounted on Revere Hinged Poles No. 199-D-30 were installed along the track. In the grandstand area, floodlights were aimed toward the finish line to heighten the intensity. Revere No. 2000 Series long range floodlights were mounted on the grandstand roof to further illuminate this area.

No. 2000 Series
Floodlight

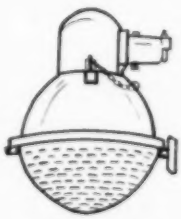


No. 3803
Eliptor Floodlight

Lighting a restricted area

The Problem: To illuminate a roadway encircling a restricted area at the Shippingport, Pa. Atomic Energy Generating Plant for both visibility and security.

The Answer: Revere Star-Lux Luminaires were installed around the entire perimeter of the restricted area, lighting the roadway and a 45° sloping embankment adjacent to it. Star-Lux Luminaires use up to 10,000 lumen incandescent lamps or 250 to 400-watt mercury lamps to provide any of the five A.S.A.-I.E.S. light distribution patterns.



No. 2311-A/2363
Star-Lux Luminaire

Write for Revere's complete catalog of outdoor lighting equipment

Revere ELECTRIC MFG. CO.

OUTDOOR LIGHTING

Revere Electric Mfg. Co. • 7420 Lehigh Avenue • Chicago 48, Illinois (In suburban Niles)
Long Distance Phone: NIles 7-6060 • Chicago Phone: SPring 4-1200 • Telegrams: WUX Niles
In Canada: Curtis Lighting, Ltd., Leaside, Toronto, Ontario

the sculptured look in lighting

SCULPTURAMA

Here is a new, richly formed Visionaire® which, like today's architecture, fuses the functional with the aesthetic. Gently curved illuminated metal sides and refined styling give these surface-mounted luminaires a modern, sculptured look. The low brightness illumination from the sides make the fixtures "blend" smoothly with the ceiling. Application versatility is greatly enhanced by a choice of single-element, fully framed diffusers including the Sunbeam-exclusive SUNLUX® prismatic plastic lens panel. The diffuser assembly opens from either side on full-length, invisible hinges. Installation and maintenance requires a minimum use of tools. Units available for 2 or 4-lamp rapid start operation.

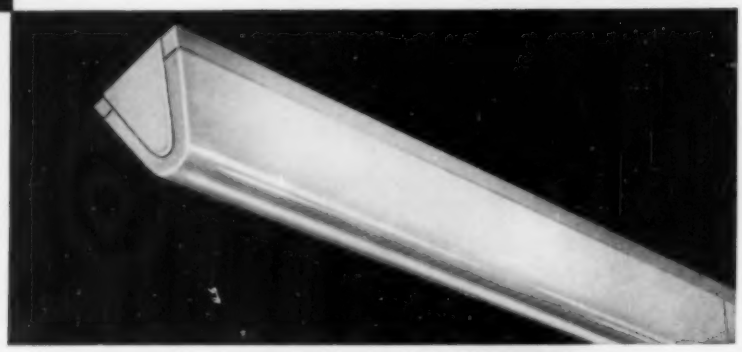
For complete details write for bulletin #A84A.

SUNBEAM visionaire LIGHTING CONTROL

ENGINEERED FOR LONG BALLAST LIFE

SUNBEAM LIGHTING COMPANY • LOS ANGELES, CALIFORNIA • GARY, INDIANA

details make the difference



MODULAR SIGHTRON: A new *4-foot* molded styrene diffuser for a smooth line of light... new *hidden hinges* for easy maintenance and positive locking... neat and clean end detail with no exposed screws, no cluttered construction. It is exclusive and carefully designed details like these that add so much to the finished appearance and performance of lighting in your commercial interiors. You'll find that Modular Sightron's glare-free illumination is ideal for office, store, school, hospital corridors and utility areas. For a 120-PAGE CATALOG-BINDER fully detailing Lightolier's wide range of architectural lighting, write Dept. IE-29.

LIGHTOLIER

ARCHITECTURAL LIGHTING • RESIDENTIAL FIXTURES • PORTABLE LAMPS

MAIN OFFICE AND FACTORY: JERSEY CITY 5, NEW JERSEY

See all the newest Lightolier designs at these authorized distributors:

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Hartford: Beacon Light & Sup. Co.
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Gary: Englewood Elec. Sup. Co.
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Paducah: Ohio Valley Sup.

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MARYLAND
Baltimore: Excello Public Serv. Corp.

MASSACHUSETTS
Boston: Mass. Gas & Elec. Light Co.
Henry L. Wolfers Inc.
Fitchburg: Service Elec. Sup. Co.
Pittsfield: Carr Supply
Springfield: Eastern Elec. Sup.
Worcester: Atlantic Elec. Sup.
Benjamin Elec. Sup.

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Detroit: Madison Elec. Co.
Michigan Chandelier Co.
Flint: Royalite Co.
Grand Rapids: Purchase Elec. Sup. Co.
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Reno: Western Elec. Dists. Co.

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Portsmouth: Mass. Gas & Elec. Light Co.

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Camden: Camden Elec. Fix. Co.

NEW MEXICO
Albuquerque: Albuquerque Dist. Co.

NEW YORK
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Binghamton: Freije Elec. Sup. Co.
Buffalo: Buffalo Incan. Light Co. Inc.
Niagara Falls: Wyan Sup. Co.
Poughkeepsie: Electra Sup. Co.
Rochester: Rowe Electric Sup. Co.
Syracuse: Superior Elec.

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Charlotte: Independent Elec. Sup.
Durham: Noland Co.
Greensboro: Elec. Sup. & Equip. Co.
Kinston: Kinston Elec.
Winston-Salem: Noland Co.

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Canton: The Electric Sales
Cincinnati: B. & B. Elec.
F. D. Lawrence Electric Co.
Cleveland: H. Leff Electric
Columbus: Elgee Elec. Co.
The Loeb Elec. Co.
Dayton: Duellman Elec. Co.
Toledo: Gross Elec.
Youngstown: Mart Industries

OKLAHOMA
Tulsa: Lawson Elec. Co.

PENNSYLVANIA
Allentown: Coleman Elec. Co.
Erie: Kraus Elec. Co.
Harrisburg: Fluorescent Sup. Co.
Hazleton: Power Elec. Co. Inc.
New Castle: Midwestern Elec. Co.
Philadelphia: Ace Lighting Fix. Co.
Gold Seal Elec. Sup. Co.
Sylvan Elec. Fix. Co.
Pittsburgh: Allied Elec. Sup. Co.
Argo-Lite Studios
Doubleday-Hill Elec. Co.
Wally Elec. Sup. Co.
Reading: Coleman Elec. Co.
Scranton: Lewis & Reif
Wilkes-Barre: Anthracite Elec. Sup. Co.

RHODE ISLAND
Pawtucket: Major Elec. Sup. Co.
Providence: Leavitt Colson Co.

SOUTH CAROLINA
Anderson: Sullivan Hdwe. Co.
Columbia: Capitol Elec. Sup. Co.
Noland Co.
Greenville: Sullivan Hdwe. Co.

SOUTH DAKOTA
Watertown: J. H. Larson Elec. Co.

TENNESSEE
Johnson City: Noland Co
Nashville: Nashville Elec. Sup. Co.

TEXAS
Dallas: Rogers Elec. Sup.
Ft. Worth: Anderson Fixture Co.
Houston: Martin Associates
San Antonio: Southern Equip. Co.

VIRGINIA
Arlington: Dominion Elec. Sup. Co. Inc.
Noland Co.
Lynchburg: Mid State Elec. Sup. Inc.
Norfolk: Noland Co.
Roanoke: Noland Co.

WEST VIRGINIA
Charleston: Goldfarb Elec. Sup. Co.
Virginian Electric Inc.
Huntington: West Virginia Elec. Co.
Wheeling: The Front Co.

WISCONSIN
Appleton: Moe Northern Co.
Eau Claire: W. H. Hobbs Sup. Co.
La Crosse: W. A. Roosevelt Co.
Milwaukee: Lappin Elec. Co.
Standard Elec. Sup.

WASHINGTON
Seattle: Seattle Lighting Fix. Co.

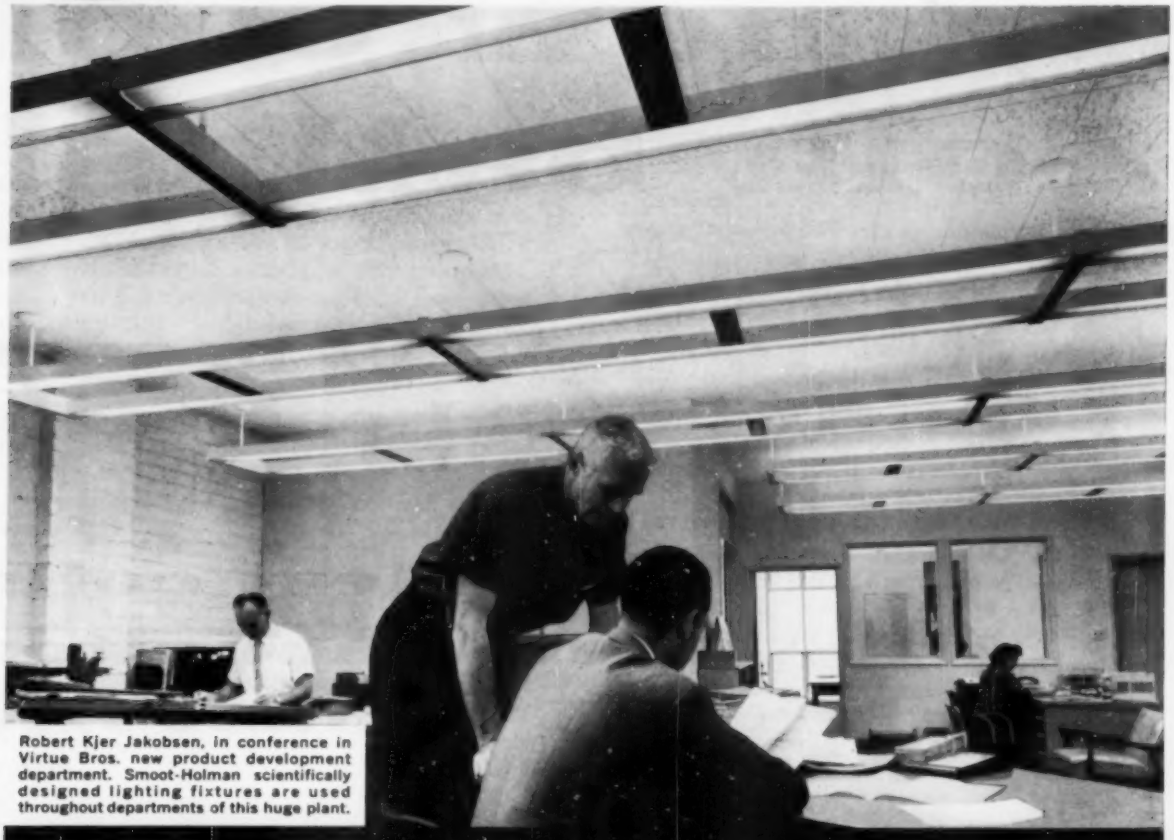
ALASKA—*Anchorage:* Northern Supply Co.

CANADA
Montreal: The Gray Elec. Co.
Toronto: Revere Elec. Dist.
Toronto Elec. Sup. Co.

HAWAII
Honolulu: Hawaiian Light. & Sup. Co.

Virtue BROTHERS OF CALIFORNIA

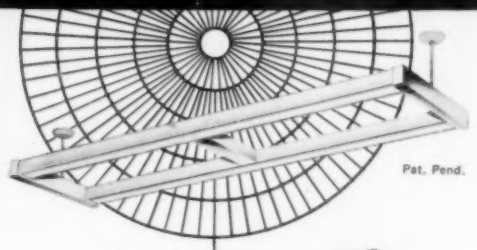
world's largest manufacturer of metal dining furniture, chooses Smoot-Holman lighting fixtures for true scientific lighting!



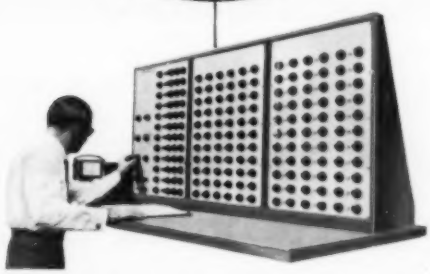
Robert Kjer Jakobsen, in conference in Virtue Bros. new product development department. Smoot-Holman scientifically designed lighting fixtures are used throughout departments of this huge plant.

scientifically designed **SMOOT-HOLMAN** lighting brings you

"TOMORROW'S LIGHTING TODAY"



Pat. Pend.



Smoot-Holman's advance design analogue computer. Used to achieve superior lighting design and unsurpassed lighting performance!

Robert Kjer Jakobsen, Chief Designer at Virtue Bros. Mfg. Co., has this to say about SMOOT-HOLMAN Lighting: "We're using Smoot-Holman Perfect Vision Luminaires in many areas in our office and plant because we feel they provide excellent light with no glare or sharp shadows. Before deciding on Smoot-Holman lighting fixtures we made a survey of a number of lighting installations and came to the conclusion that the Perfect Vision unit was the ideal one from many angles.

"In making our decision we took into consideration a number of things. Of first importance was to get a good lighting job ... which the Perfect Vision Luminaires give. Other important advantages we found in the Perfect Vision Fixture were ease of installation and maintenance. With maintenance labor costs what they are, we have to consider not only the initial cost of fixtures but maintenance as well. We have found that the Smoot-Holman Perfect Vision Fixture meets all our requirements perfectly."

SMOOT-HOLMAN CO.

Inglewood, California

new cool Sola ballast

easily passes "in-fixture" heat tests

coolest coils and capacitor give full ballast life

SOLA
CONSTANT
Sequenstar
MADE UNDER ONE OR MORE OF THE FOLLOWI
U.S. PAT'S. 2806199-2346621-2489245-2552111
CANADIAN PAT'S. 439590 (1947) AND PATENT
FOR 2-T12 40 WATT RAPID START LAMI
CAT. NO.670-109. HIGH P.
118 VOLTS 0.80 AMP
LAMPS MUST BE WITHIN 1" OF
SOLA ELECTRIC CO. CHICAGO, 5

Ballast for two 40-watt rapid-start lamps
Catalog Number 670-109

no price penalty for this premium performance

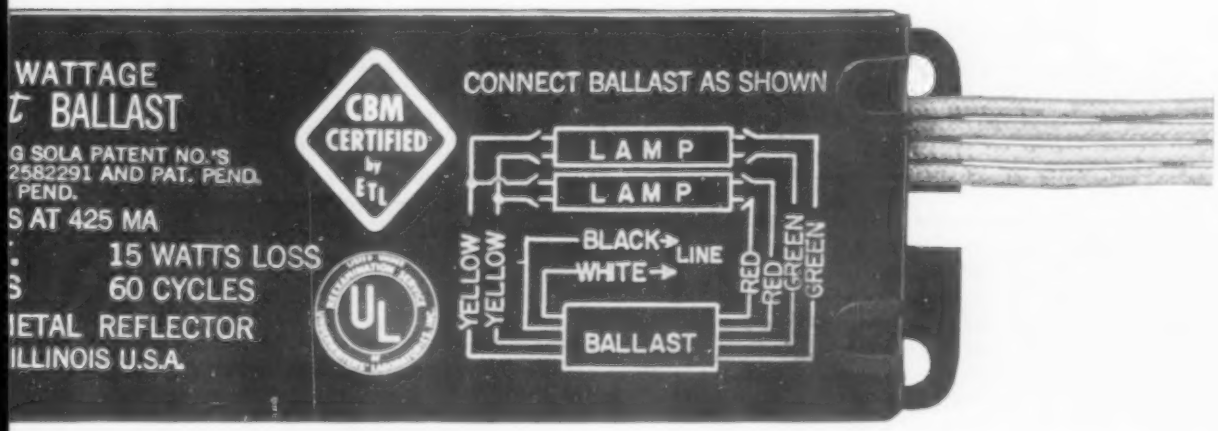
Now—totally new electrical and mechanical design sets highest standards of "in-fixture" ballast performance. This new two-lamp, 40-watt, rapid-start ballast is dramatic evidence of progress made possible by Sola's philosophy of conservative design. Sola views the ballast as integral with the lighting fixture and has consequently built its new ballast to pass exacting "in-fixture" tests and for actual operation under the most demanding conditions.

This new rapid-start ballast is designed to give only a 42°C coil-temperature rise when tested according to U.L. and E.T.L. methods. New circuitry increases ballast efficiency through reduced wattage loss.

The new ballast was tested in a four-lamp fixture, completely enclosed and surface-mounted on acoustical material. Temperature in the fixture channel was 18°C hotter than the usual 40°C ambient of U.L. and E.T.L. tests. Despite these severe test conditions, the following impressive results were recorded.

- *Maximum coil temperature was 89.3°C. This is 15°C cooler than the limit of Class A insulation.*
- *Temperature of the capacitor's case under this especially severe test was within the heat limits of the capacitor's insulation.*
- *The "hot-spot" temperature on the ballast case was 81°C. This is 5°C cooler than premium-priced ballasts similarly tested, and it is 9°C cooler than the maximum allowed under U.L. fixture requirements.*

This new level of cool ballast operation contributes to full ballast life. These improvements result from Sola's concept of ballast engineering that treats the ballast as integral with a fixture and part of the complete lighting system rather than as an isolated component. This approach has produced a major engineering breakthrough — the elimination of thermal insulating barriers which formerly confined ballast heat within the coil and capacitor compartment. Now, heat is far more easily dissipated through the case and fixture. The combination of fixture and Sola ballast now team up for cool, efficient, trouble-free operation.



Send for test ballasts or literature

Sola will furnish fixture manufacturers with samples of this new ballast. Write to us on your business letterhead, and a Sola sales engineer will promptly supply your test ballasts. Sola welcomes the challenge of having you evaluate this cool new ballast in your own fixtures. If you wish merely to examine data on the new model, please request Bulletin 3B-FL-352. Write to the Manager, Lighting Sales.

Sola Electric Co.** (A Division of Basic Products Corp.), **4633 West 16th St., Chicago 50, Ill.

NOW! ...a 4′ x 4′ Recessed Unit to complement Sylvania's New Troffer Series

Now at your command—shallow recessed fixtures in 1′, 2′ and 4′ widths to fit all modern ceilings.

Sylvania's new Troffer Series represents completeness in every sense of the word. Three separate housing designs are available to fit quickly and easily into every type of ceiling construction. You get complete choice of shieldings in both one and two foot widths—and in four and eight foot lengths. Matching incandescent Accent Units allow for pattern lighting or the creation of special effects.

To complement this Troffer Series and to expand the design potential of recessed lighting systems, Sylvania now offers a versatile 4′ x 4′ shallow recessed fixture featuring the same clean, smart appearance and the up-to-date design advantages which permit simpler and faster installation. This attractive 4′ x 4′ unit places another distinctive and useful lighting tool in your hands.

For complete information on Sylvania's Troffer Series and 4′ x 4′ units, write to:

SYLVANIA LIGHTING PRODUCTS
A Division of SYLVANIA ELECTRIC PRODUCTS INC.
Department 59-1
One 48th Street, Wheeling, West Virginia

The advanced features found in Sylvania's Troffer Series—shallowness, concealed hinges and latches, variety of housings and shieldings, snap-up hanger and many others—are typical of the inherent advantages built into each and every Sylvania fixture line.

Take a look at Sweet's Architectural File for a quick review of Sylvania's complete and modern line. Better yet—send for a complete fixture catalog today. Leaf through it and you'll soon discover the wide choice of fluorescent lighting equipment offered by Sylvania.

GO MODERN WITH LIGHTING BY **SYLVANIA**

Fluorescent Lighting Fixtures and Systems

BEST FIXTURE VALUE IN EVERY PRICE RANGE

LIGHTING • TELEVISION • RADIO • ELECTRONICS • PHOTOGRAPHY • ATOMIC ENERGY • CHEMISTRY-METALLURGY

Meet Today's Needs for Higher Industrial Lighting Levels with fixtures bearing the

RLM Quality Label

New, Higher I.E.S. Industrial Lighting Recommendations make the RLM LABEL MORE IMPORTANT THAN EVER BEFORE!

Q *Why do the new, higher, lighting levels now recommended by the Illuminating Engineering Society make the* **RLM LABEL** *More Important than ever?*

A *You can't have Quality Lighting without* **QUALITY LIGHTING FIXTURES.**

Higher Lighting levels put more importance on conformance to highest RLM concepts of lighting fixture design, construction, performance and maintenance features.

Q *What is meant by... "Only the RLM Label provides this essential warranty of* **UNIFORM QUALITY..."?**

A *It takes over* **1000 WORDS** *to cover the RLM specifications* for each type of fixture. Further, it requires the services of the Electrical Testing Laboratories of New York (an independent engineering organization) to insure uniform and consistent conformance by making periodic tests from samples secured both from the production lines and the field stocks of every participating manufacturer. The simple passing of the tests by the submission of a sample or samples is not enough. To be entitled to the RLM Label, fixtures are subject to continuous examination and must uniformly meet the RLM quality Spec's so as to insure unvarying quality from fixture to fixture.

R-525

RLM STANDARDS INSTITUTE, INC.
Suite 8232, 326 W. Madison St.
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THIS COUPON IS FOR MEN WHO WANT *ALL THE FACTS*

☐ Please send the FREE RLM Specifications Book containing latest Specifications and 10 pages of facts about the RLM Label. Also, a complimentary copy of the New Higher I.E.S. Industrial Lighting Recommendations.

Name ..... Title .....

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Address .....

City ..... Zone ..... State .....

RLM STANDARDS INSTITUTE

the work's lighter when the light's brighter!

WESTINGHOUSE SUPER-HI™ FLUORESCENT LAMPS ARE 2½ TIMES BRIGHTER!

Rosie's just collected an armful of posies from the boss. Since they put in Westinghouse Super-Hi fluorescent lamps, everything's looked brighter (2½ times brighter than with regular fluorescents, in fact) and Rosie's efficiency has soared.

Of course what Rosie didn't know is that:

- "Ultralume"™ phosphors maintain maximum light levels for the life of the lamp.
- Special cooling chambers give *longer life*, as well as more light.
- New leads are chromium-vanadium plated to eliminate end-darkening.
- Smooth, slim design gives uninterrupted brightness all around the tube . . . much lighter weight for safer, easier handling.
- They're interchangeable . . . can be used in any fixtures designed for new high intensity lamps.

This all made the boss very happy, too. He found not only were morale and efficiency higher, but that he could save money while getting more light from the same number of fixtures.

Why not get the details for yourself? Just call your local Westinghouse agent, or write—Westinghouse Lamp Division, Dept. 57-L-5, Bloomfield, New Jersey.

YOU CAN BE SURE...IF IT'S Westinghouse

Background for Policy-Making . . .

this distinguished Presidential Office

. . . illuminated fittingly by

LITECONTROL

For making important decisions . . . for receiving important guests, this top executive panelled office at Holliston Mills has been functionally planned and equipped. It and the conference room (small photo) are part of a newly remodelled, two-story office building and are a tribute to the architects.

Litecontrol luminous ceilings are used in most of the private offices on the second floor. An unusual feature is the mounting of the ceilings at a slight (5°) angle. They slope downward from the window wall to the inside wall.

Another interesting feature is the "free-floating" character of the ceilings — they do not extend completely to the walls. There is a space of some 12 to 15 inches all around each luminous ceiling.

Plastic grid louvers are the diffusing medium and provide excellent intensity as well as maximum comfort in seeing. Even in the photos, the very low brightness of the louvers is apparent. (The detail in the louvers is clear despite the high intensity.)

Remember, LITECONTROL accomplishes results like this with *standard* fixtures that *save money!* Can we help *you?*

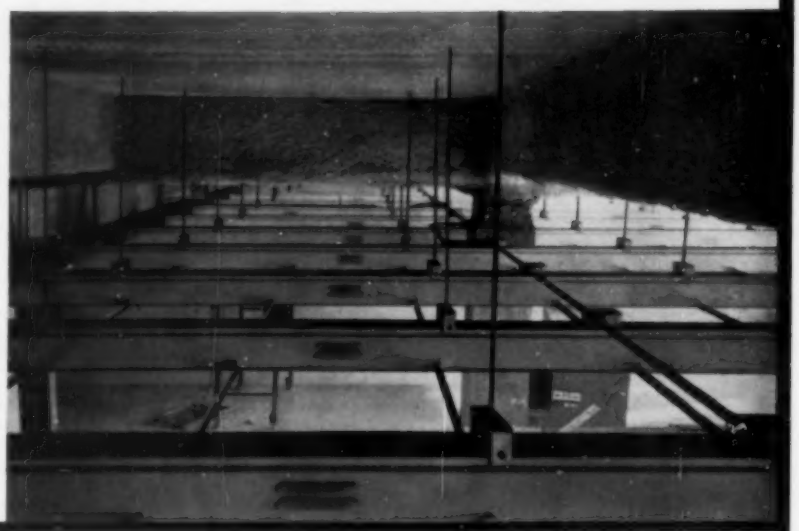
INSTALLATION: Holliston Mills, Inc., Norwood, Mass.
AREA SHOWN: President's Office and Conference Room
ARCHITECT: Korslund, le Normand & Quann, Inc., Norwood, Mass.
ELECTRICAL ENGINEER: Martin E. Keane Associates, Boston, Mass.
ELECTRICAL CONTRACTOR: Hixon Electric Co., Boston, Mass.
DISTRIBUTOR: General Electric Supply Co., Boston, Mass.
FIXTURES:
Litecontrol Luminous Ceilings, using molded plastic grid louvers, 45° x 45° shielding, with 40 watt Rapid Start strip fixtures on 24" centers
INTENSITIES:
President's Office and Conference Room, average 95 foot-candles in service

LITECONTROL
Fixtures
KEEP UPKEEP DOWN
LITECONTROL CORPORATION,
36 Pleasant Street, Watertown 72, Massachusetts

DESIGNERS, ENGINEERS AND MANUFACTURERS OF FLUORESCENT LIGHTING EQUIPMENT DISTRIBUTED ONLY THROUGH ACCREDITED WHOLESALERS

BIRD'S EYE VIEW OF *Quiet-Light*

QUIET-LIGHT recessed troffers are shown from above, suspended by slide grip hangers from the original ceiling. Wall angles are mounted and spacer bars inserted between rows of troffers and wall angles.



MAN'S EYE VIEW OF *Quiet-Light*

In completed installation, acoustical panels are suspended on QUIET-LIGHT troffers, spacer bars and wall angles. Diffusers of ⅛" thick white polystyrene extruded plastic extend 1" below ceiling line, directing some illumination to ceiling area.

QUIET-LIGHT, a new kind of lighting and acoustical ceiling system cuts construction costs because it eliminates the separate T-bar grid required by ordinary suspended ceiling systems. It provides evenly diffused wall-to-wall quality lighting with efficient acoustics at decidedly lower cost. Write for catalog and specification sheet today.

metco Lighting

Illustrated above, QUIET-LIGHT installation in Detroit (North) office building for occupancy of International Business Machines Corporation.

Architects: Pedersen & Tilney, New York City
Consulting Engineers: Jaros, Baum & Bolles, New York City
Electrical Contractor: Harlan Electric Co., Detroit
Acoustical Contractor: Detroit Fibreglas, Insulation Div., Detroit

SOLD ONLY THROUGH QUALIFIED ELECTRICAL DISTRIBUTORS

METALCRAFT PRODUCTS CO., INC., 6225 State Road, Phila. 35, Pa. • DE 2-7300

NEW...from APPLETON

24" High-Bay Mercury Vapor Lighting Units

higher production . . . fewer rejects . . . improved employee relations . . . extended safety records

more effective illumination at the work level!

Here is a precision-designed lighting unit for large industrial interiors and high-bay plant areas. High illumination levels without uncomfortable glare... Ventilated hood for lower operating temperature and minimum dirt accumulation... the new APPLETON 24" High-Bay Mercury Vapor Lighting Unit is a unique combination of technical features which give you more useable illumination at the work level. Available in: 1 pc. socket type construction or with the 2 pc. APPLETON DISKONECT time-saving maintenance feature. (Permits both lamp and reflector to be removed as a complete unit without disturbing wiring!) Reflecting surfaces are of ALZAK* processed aluminum. Available for concentrating or spread-type illumination distribution. For use with 1,000 Watt Mercury Vapor Lamps, this new APPLETON 24" High-Bay Mercury Vapor Lighting Unit is designed to meet your specific needs. As with all APPLETON Industrial Lighting Products... you can *see* the difference!

*A proprietary term of Aluminum Company of America

Sold Through Franchised Distributors Only

APPLETON ELECTRIC COMPANY
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"ST" Series Connectors

Outlet Boxes

Malleable Iron Unilet Fittings

Reelites

it's a fact...

P&K

ALL ALUMINUM LIGHTING STANDARDS

"MOST FOR YOUR MONEY"

Before you specify another lighting standard, take a hard look at your costs. Look at the cost per unit to be sure, then consider the cost of installation. In this regard, nothing compares with the ease of handling light weight P & K aluminum standards. They speed installation, save time and labor. Then compare your maintenance costs. P & K aluminum standards never require painting, not on installation nor at any other time. How much can you save on this factor alone? As for simple good looks, P & K aluminum standards are in a class by themselves. They'll confirm your good taste as well as your sound business judgment for years to come.

You'll find a wealth of helpful information in P & K street and highway lighting brochures. Write for your copies.

HERE'S A COST CUTTING IDEA:

In this on-the-job photo, the crew is changing the glassware on the luminaire. Instead of inadequately cleaning it on the spot, they replace it with a clean one. Then, at the end of the day's run, they bring the dirty globes back to the shop for a really thorough cleaning, and out again, a day or two later to be used as replacements for others. This simple maintenance trick results in a better job, done faster, at lower costs. Of course, the P & K standard never needs maintenance.

PFAFF & KENDALL

84 FOUNDRY ST., NEWARK 5, N. J.

NOW YOU CAN HAVE BOTH

FAMOUS ALL-BRITE HI-OUTPUT INDUSTRIAL

PLUS

A NEW 30° MATCHING LOUVER for GUIDED LIGHTING . . .

ALL-BRITE
ALL NEW
LOUVER Power Groove

DESIGNED SPECIFICALLY FOR ALL THESE GREAT LAMPS:
VHO, SHO, Power Groove

BUILT LIKE A HEAVY-DUTY TRUCK:
STRONG, SOLID, SAFE

send for catalog and data sheet

All-Brite
LIGHT OF AMERICAN COMMERCE

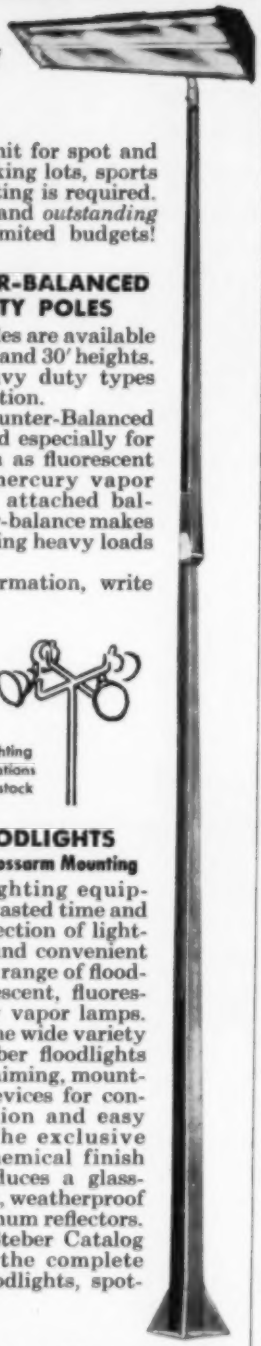
ALL-BRITE FLUORESCENT FIXTURES, INC.
352 SHAW ROAD, SOUTH SAN FRANCISCO, CALIF.

PLANTS ALSO IN LOS ANGELES AND SEATTLE.
IN CANADA: ALL-BRITE LIGHTING (B.C.). VANCOUVER. B.C.
REPRESENTATIVES THRUOUT THE UNITED STATES AND CANADA

NOW—FOR BIG OUTDOOR LIGHTING JOBS

STEBER *has the right*

Units, Accessories, Prices!



The Steber line offers every popular type of unit for spot and floodlighting loading docks, railway yards, parking lots, sports areas, plazas—anywhere good, economical lighting is required.

When you specify *Steber*, dollars go farther and *outstanding* lighting installations are achieved on even limited budgets!

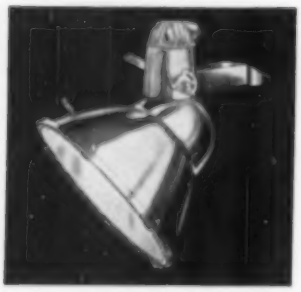
STEBER FLOODLIGHTS

NEW COUNTER-BALANCED HEAVY DUTY POLES

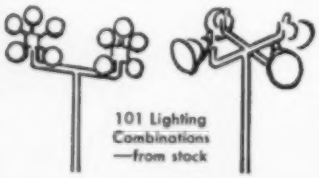
Steber hinged poles are available in 16′, 18′, 20′, 24′ and 30′ heights. Standard or heavy duty types for every application.

New Steber Counter-Balanced poles are designed especially for heavy loads such as fluorescent floodlights or mercury vapor floodlights with attached ballasts. The counter-balance makes raising and lowering heavy loads easier and safer.

For more information, write for catalog.



SERIES 4000
SPORTSLITER



STEBER FLOODLIGHTS

for Pole, Wall or Crossarm Mounting

Steber floodlighting equipment eliminates wasted time and effort—makes selection of lighting units simple and convenient by offering a wide range of floodlights for incandescent, fluorescent and mercury vapor lamps.

In addition to the wide variety available, all Steber floodlights feature the latest aiming, mounting and wiring devices for convenient installation and easy maintenance. The exclusive Steber electro-chemical finish "ANODAL" produces a glass-hard dirt-repellent, weatherproof finish on all aluminum reflectors.

Write for the Steber Catalog today. Examine the complete Steber line of floodlights, spotlights and poles.

SERIES 2400
700-1000 WATT MERCURY VAPOR

Lighting Units **STEBER** *for Every Need*

STEBER MANUFACTURING CO., DEPT. 66-B, BROADVIEW, ILL.

Steber Manufacturing Co. of California, 242 S. Anderson St., Los Angeles 33, Cal.

Divisions of The Pyle-National Company

PYLE-STEBER LTD., 33 Ingram Drive, Toronto 9, Canada

Subsidiary of The Pyle-National Company

(*Continued from page 28A*)

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(*Continued on page 48A*)

Revolutionary LIGHTING SYSTEM!

EXCLUSIVE FEATURES:

- NEW U TUBE LAMPS — 96 T-12 HOT CATHODE
- HIGH FOOT CANDLES at LOWEST INSTALLATION COST
- EASY & QUICK INSTALLATION . . . CLEANING SIMPLEST IN INDUSTRY
- INSTALLED WITH PATENTED SELF-SUPPORTING BAR-JOIST

TRANSOLITE SYSTEM

TRANSOLITE FIXTURES can be used as shown . . . or with *new* diffusers hung directly from unit. Either open plastic egg-crate with ½" 45° cut-off—or, with *new* plastic egg-crate 9" square openings into which *new* type vinyl pan is dropped. Esthetically pleasing — continuous *unbroken pattern* diffusers.

TRANSOLITE SYSTEM

- Hangerless installation, if desired
- Eliminates construction alterations
- Requires NO supporting rails for diffusers
- Requires NO wall moulding
- NO interference with sprinklers
- NO dark shadows from air-conditioning vents

For details contact:

R. W. Lester, Pres. **TRANSOLITE CORP.**

Manufacturing Illuminating Engineers—Complete Engineering Service

550 - 5th Avenue, New York 36, N. Y. • ph: PLaza 7-6620

(*Continued from page 46A*)

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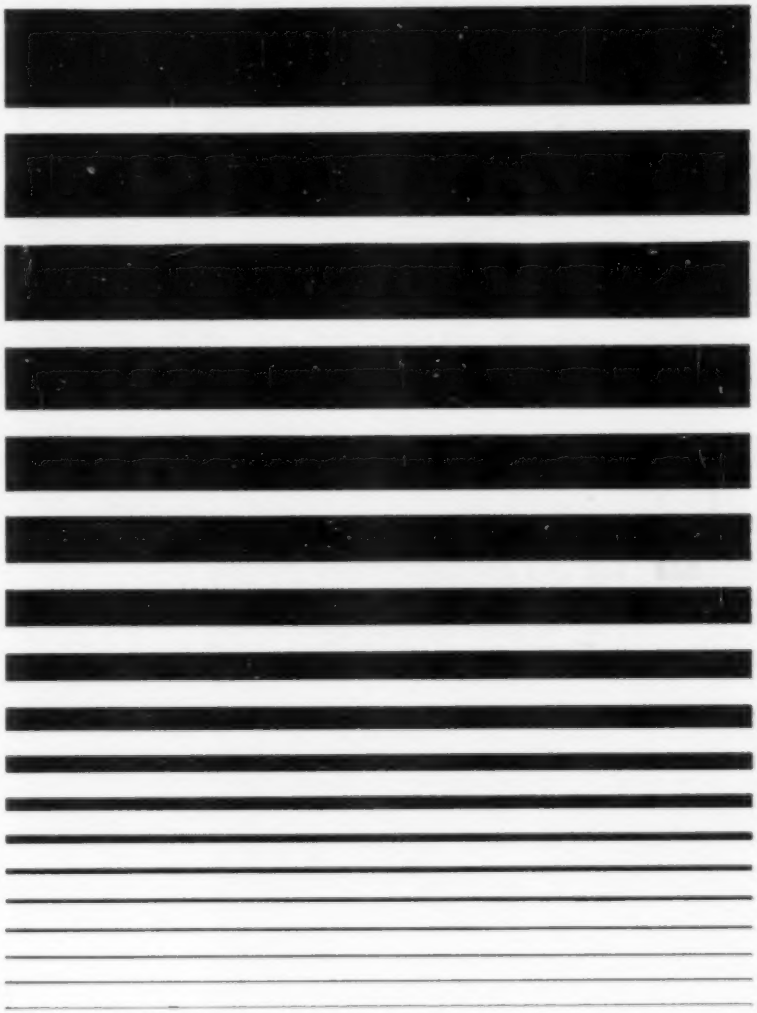
Breaking barriers . . . Revolutionary change in electronic dimmer control



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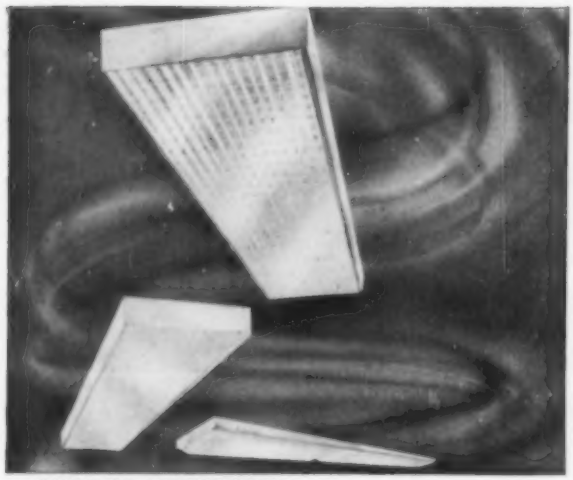

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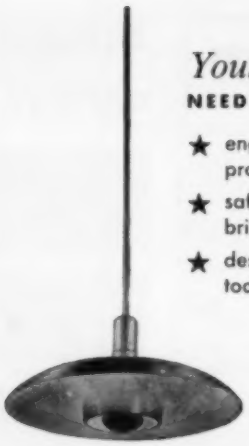

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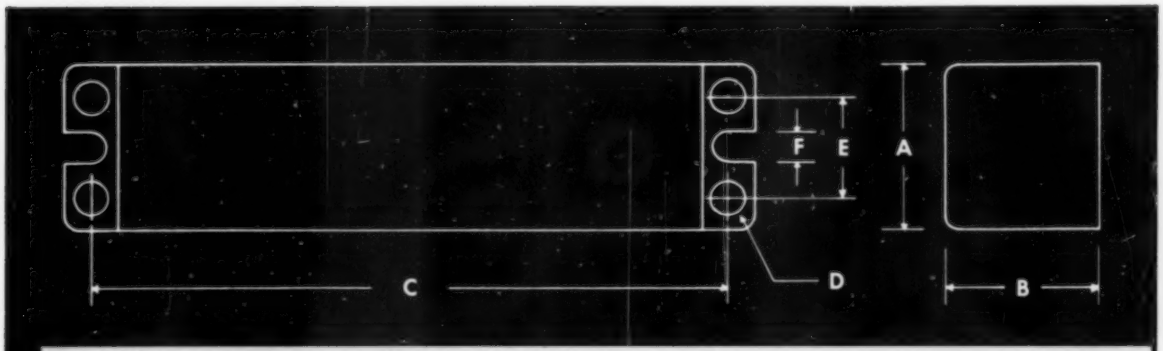
HOW CBM ASSURES YOU BETTER BALLAST VALUE

New recommended standards for ballast cross section and mounting dimensions aid fixture designers, architects, engineers, add flexibility for purchasing and replacement.



	DIMENSIONS (INCHES)															
	(MAXIMUM) CROSS SECTION		LENGTH (NOMINAL)												CORNER MTG. HOLES		CENTER (MAX.) MTG. SLOT
	A (WIDTH)	B (HEIGHT)	C (MOUNTING)												D (DIA.)	E (WIDTH)	F (WIDTH)
1	2-3/8	1-11/16	6	7-13/16	8-57/64	9-17/32	11-1/4			14-7/16	15-7/16				15/64 or 7/32	1-11/16	5/16*
2	2-13/16	2			8-57/64		11-1/8		13-3/4						15/64 or 7/32	2	5/16
3	3-1/8	1-25/32			8-57/64		11-9/64		13-3/4						15/64 or 7/32	2	5/16
4	3-3/16	2-3/8			8-57/64		11-9/64		13-3/4					18-5/8	15/64 or 7/32	2	5/16
5	3-3/16	2-5/8			8-57/64		11-9/64	13	13-3/4		15-5/8		16-1/8	18-5/8	15/64 or 7/32	2	5/16

*Drawn cases use center slot only for mounting.

HERE'S an example of CBM at work to give the fluorescent lighting industry better ballast value. As the result of a study by one of the technical committees of the Certified Ballast Manufacturers Association . . .

22 different cross section dimensions for ballasts were cut to 5;

35 different mounting lengths were reduced to 14.

Obviously, this offers practical advantages to fixture manufacturers and engineers in the design of new units—and makes for a wider choice of component sources.

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